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SMALL CAMERA VERTICAL AERIAL PHOTOGRAPHY

by

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B.S. University of Montana, 1961

Presented in partial fulfillment of the requirements for the degree of

Master of Forestry

UNIVERSITY OF MONTANA

1968

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FEB 14 1969
Date

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J.P.M.

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INTRODUCTION

Resource managers rely heavily on aerial photographs as a management tool. These photographs provide a valuable source of information about the characteristics of our natural resources by providing a permanent, reproducible record of the resource. Seeley (27) recognized this fact and stated, "Looking down from a height of thousands of feet on a tract of country, one gets a comprehensive view of the area, the proverbial 'birds-eye-view' obtainable in no other way. The camera, looking down in this way, furnishes a permanent record of this comprehensive view...".

More than half of the land area of the earth has been photographed from the air at least once, and nearly all of the United States has been photographed from the air (3). Most of the United States photography is of the single lens vertical type that has been taken commercially or by one of the agencies of the Federal Government. Prints of this photography can be obtained for use in solving many resource problems. However, this aerial photography may not provide the type of information desired by the resource manager.

Conventional aerial photography may be several years old, the scale may be too large or too small, or the film type may not provide the desired information. When the available photography does not meet his requirements, the resource manager must either contract for new aerial photography or resort to costly on-the-ground methods of obtaining the needed information.

If the resource manager elects to purchase new conventional aerial photography, he must decide on the film type and the scale that will provide him with the data he needs. The cost of experimenting with conventional photography to determine the best film type and scale is generally too expensive.

The resource manager often needs current coverage of a small area. The cost of obtaining this coverage with conventional photographic methods is usually prohibitive.

Small camera vertical aerial photography can be used as an economical answer to the problems of out-dated information, film type, scale and small area coverage. This photography is obtained by using small cameras hand held or mounted in a single engine airplane.[1] Aerial photography obtained this way can provide coverage that fits the need and offers an opportunity to experiment with film-filter combinations, scale and other techniques.

In 1961, the University of Montana, School of Forestry began testing methods of taking small camera photography. Since that time, small camera methods have been used many times to produce aerial photography for a variety of applications.

The objective of this paper is to develop a set of guidelines that will provide the resource manager with the information needed to obtain small camera photography. The work is based on past literature and on the research done at the University.

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[1]Small cameras (often termed miniature) make negatives up to 2¼ X 3¼ inches and includes the 35mm and 2¼ X 2¼ inch models. This paper recommends 35mm and 2¼ X 2¼ inch cameras, but does not ignore the possible application of smaller or larger cameras. Small camera vertical aerial photography will be referred to as small camera photography in the remaining sections of this paper.

LITERATURE REVIEW

Several researchers have developed solutions to the problem of obtaining aerial photography that provides the information they desire. MacFadden (20), Francis (10), Willingham (35), Strandberg (30) and Witmer (36) utilized 35-mm cameras and light airplanes to obtain usable aerial photographs.

MacFadden (20) used a 35-mm camera and a light airplane to obtain low and high oblique aerial photographs for geographic field research in California. He pointed out that existing aerial photography has the disadvantage of being taken for mapping purposes or for purposes other than for geographic research. It was indicated that there is a need for current aerial photography for many research problems. He recommended 35-mm aerial photography as a means of acquiring current information.

The importance of delineating individual trees of commercial value led to research into the use of infrared and color film for type mapping of the tropical forests of Ghana. Francis (10) observed that mahogany (Khaya ivorensis) had a coppery-colored first flush and used 35-mm color film in a miniature camera to determine if the identification of this species could be improved through the use of color film. The results of the 35-mm photography were promising and led to further tests with aerial color film in aerial cameras.

Willingham (35) reported on the procedures and made recommendations on how to obtain vertical aerial photographs with a 35-mm camera. He pointed out that vertical aerial photographs are extremely valuable in the management of forest lands, but the forester has not been able to realize full value because the available photography does not always meet the requirements of the forester. He listed the advantages of vertical aerial photography with a 35-mm camera as: 1) availability of current information 2) small area coverage at a reasonable cost 3) no compromise on scale or tonal quality 4) opportunity for variation 5) inexpensive to carry out 6) low equipment investment and 7) weather advantage.

Strandberg (30) outlined techniques for obtaining and analyzing 35-mm oblique aerial photographs. The techniques were developed to provide faster, more efficient and more economical reconnaissance methods of collecting information about water pollution. A frequent complaint of available aerial photography has been that it is several years old or is taken at the wrong season of the year. The techniques outlined were designed to overcome these handicaps.

Witmer (36) discussed the use of multispectral imagery in geographic analysis. A hand-held 35-mm camera and a light airplane were used to obtain oblique black and white infrared and color infrared aerial photographs concurrent with a flight which obtained thermal infrared images of the same area. The 35-mm photography, the thermal infrared imagery and conventional vertical panchromatic black and white aerial photography were used in a comparative analysis of physical and cultural geographic features in Florida.

Stereo-photography from a helicopter is another method that has been used to overcome the inadequacies of conventional aerial photography. In 1957 Gerlach (11) proposed a method of obtaining aerial photographs from a low-flying helicopter for timber sampling. Two aerial cameras could be mounted on a 16 foot boom, perpendicular to the line of flight, through the cockpit, with a lever to control the attitude of the cameras. The cameras would be triggered at the same time to produce vertical stereo-pairs of chosen plots. He concluded that photography obtained in this manner could provide for more accurate measurements and easier identification of tree species for timber sampling.

Avery (4) used two small cameras (2¼ X 2¼ inch format) mounted thirty-six inches apart on a bar, parallel to the line of flight, hand-held outside the cockpit of a helicopter, to obtain large scale stereo-photography for forest sampling. The results of this experiment were promising. It was concluded that camera separation of at least ten to fifteen feet would be necessary to obtain good three dimensional imagery at altitudes higher than 400 feet.

Lyons (17,18,19) conducted a series of experiments in Canada to determine the utility of large scale stereo-photography for forest classification and sampling. He used two aerial cameras mounted on a fifteen foot boom beneath a helicopter. Methods were tested for obtaining stereo-photography that is free of vibration blur. Also, methods of determining accurate flying height were tested to insure adequate parallax for tree height measurement. The results were promising and Lyons concluded that this type of forest sampling is feasible.

The literature reviewed provides specific indications of the successful use of small camera photography. The literature, however, provides little information that can be readily translated into procedures and methods for use by resource managers.

SMALL CAMERA VERTICAL AERIAL PHOTOGRAPHY AT THE UNIVERSITY OF MONTANA

The first small camera photographic project at the University of Montana was carried out in 1961. Its purpose was to develop methods and procedures for obtaining small camera photography and was initiated by Professor Fred Gerlach. The University Graduate Council Research Committee provided a small grant for the rental of equipment and purchase of film and processing. Two missions were flown with this grant. The first developed methods and procedures, and the second obtained vertical aerial photography for use in mapping condition classes by the Office of the State Forester. Figure 1 compares the quality of a 35-mm aerial photograph obtained on the first flight with a portion of a conventional 9 X 9 inch aerial photograph.

Since 1961, many small camera missions have been flown for a variety of uses. These include:

1. A range management study concerned with the delineation of sagebrush groups. Figure 2 is an example of the photography on which the sagebrush groups were successfully identified.
2. The successful mapping of clearcut logging boundaries (figure 3).
3. Large scale aerial photography obtained for a logging road reconnaissance study by students (figure 4).
4. A water resource research project concerned with the relationship of vegetation, water and soil moisture. This is a current project which involves photographing the test area periodically with four film-filter combinations (figures 5 and 6).

An analysis was conducted to determine if reliable measurements could be obtained from small camera photography. Measurements taken

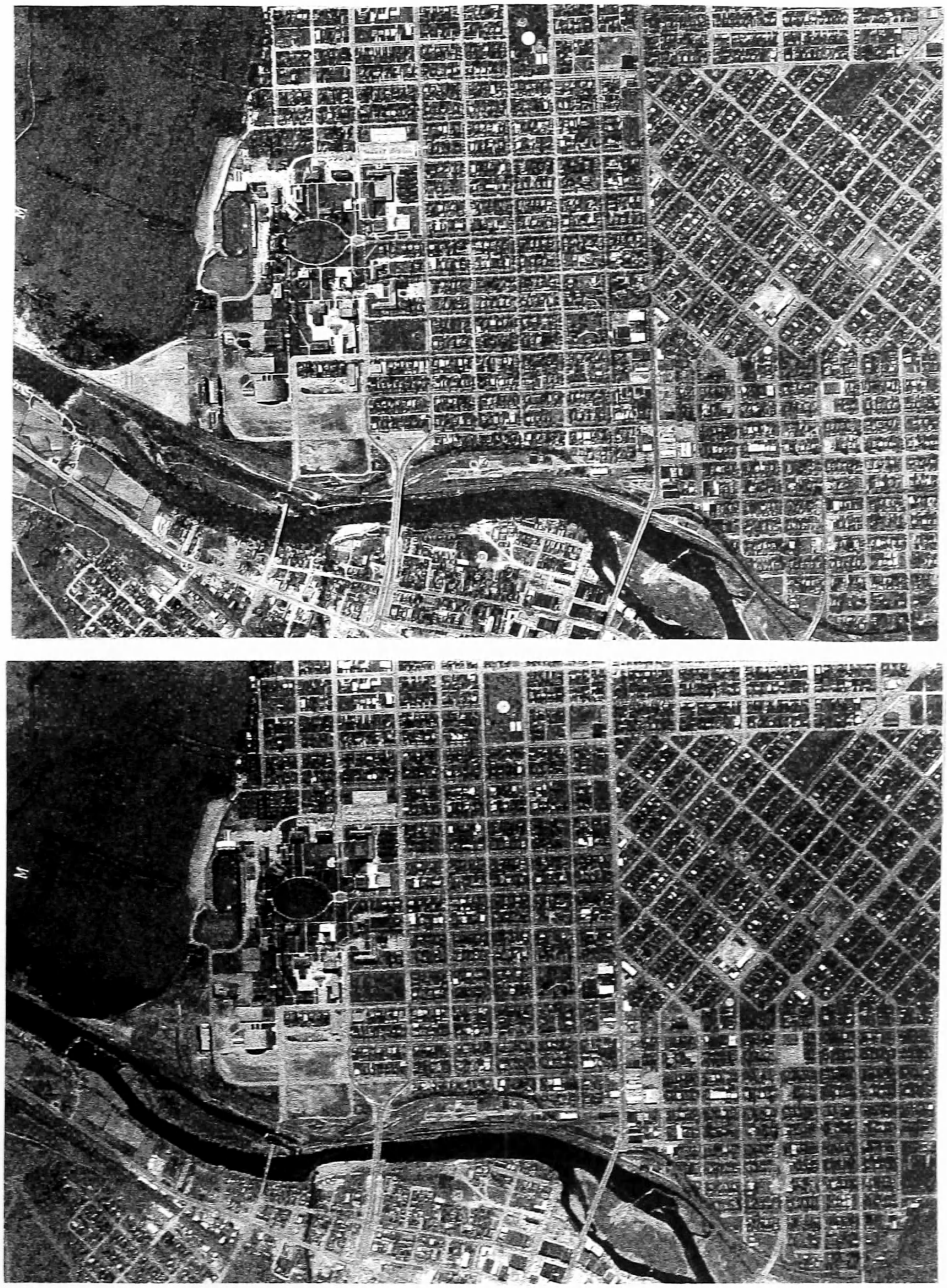


Figure 1. Upper photo - portion of a conventional vertical 9 X 9 inch aerial photograph taken in 1961 (40). Lower photo - 35-mm vertical aerial photograph taken during the first flight in 1961. Panatomic-X film exposed with a Minolta camera and a 35-mm focal length lens. Taken out the baggage door of a Cessna 180 airplane (37).

Figure 2. Aerial photograph of range land showing sagebrush development. Sagebrush groups were successfully delineated on this infrared photography (37)

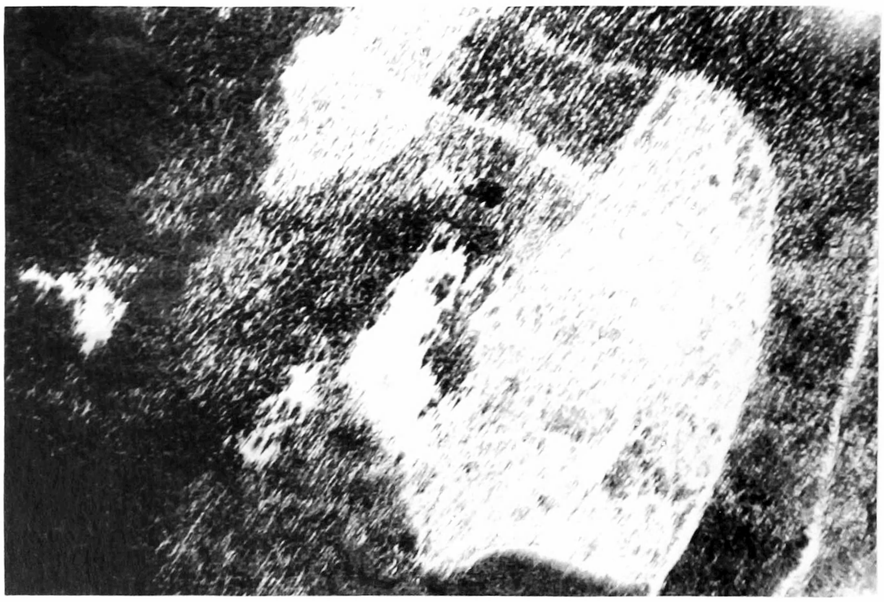


Figure 3. Winter infrared aerial photo secured for mapping clearcut logging boundaries (37)

Figure 4. Aerial photography taken for use by students in a road reconnaissance study. Kodak Plus-X film exposed with a Hasselblad 500C (37).

from small camera photo enlargements were compared to identical measurements taken from conventional 9 X 9 inch photographs. The results of this analysis revealed that measurements can be taken from small camera photography and used in reconnaissance surveys, where complete reliance on the measurements is not a factor.

Experience has shown that the quality of the photographic image has been generally acceptable. However, the photography obtained has not always supplied the needed information. Failure to do so is frequently due to: inadequate flight planning, adverse flight conditions, insufficient pilot briefing, or unfamiliarity with the photographic

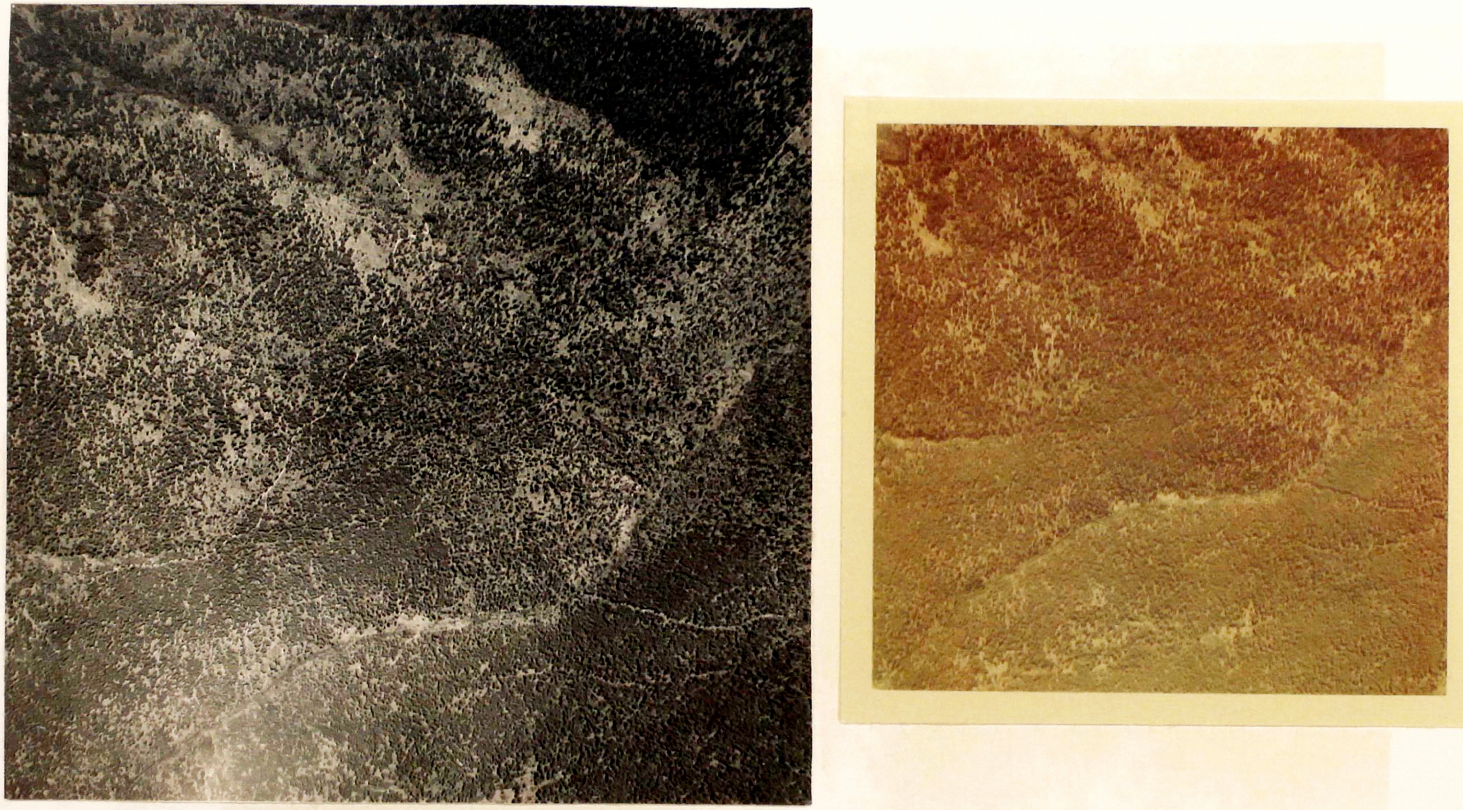


Figure 5. Example of acceptable panchromatic and color aerial photographs. This photography provides useful information for a water resource research project. Note the hotspot on the lower left portion of the panchromatic photograph. See page 22 for a discussion of the hotspot.

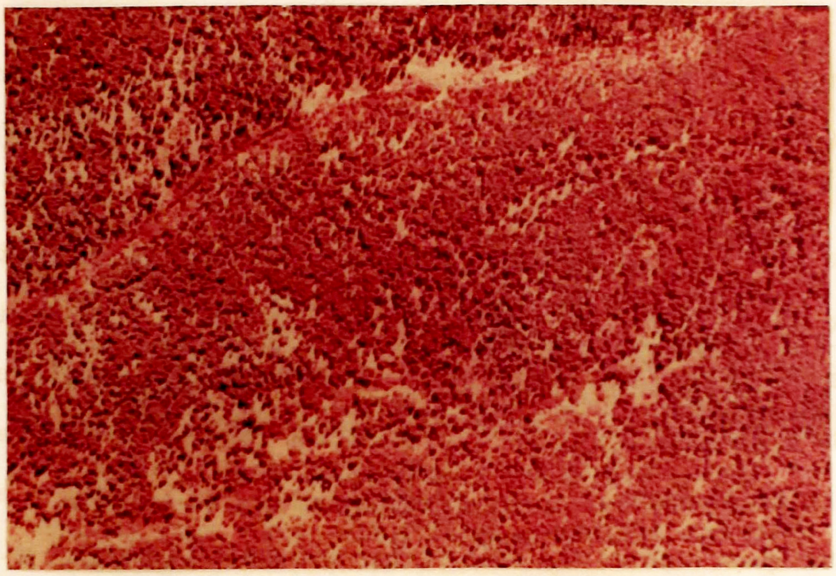


Figure 6. Example of acceptable infrared color and infrared black and white aerial photography taken to study the relationship between vegetation, water and soil moisture (37).

equipment used. These problems can be reduced by thorough pre-flight planning.

A small camera mission was planned by the author for the purpose of obtaining duplicate coverage of a forested area on panchromatic and color film. The objective was to compare the qualities of the two film types for identification of the major tree species in Western Montana. The mission failed to meet the objective for two reasons: poor pilot briefing and photographer error. The pilot was not adequately briefed on the ground control to be used. Therefore, the flight lines were not maintained which resulted in lack of duplicate coverage and poor coverage of the desired area.

The photographer exposed the color film (Kodacolor-X) through a yellow filter (K2) which produced yellow-toned prints. An attempt to improve the quality of the photography with color correction printing failed. Figure 7 is an example of the panchromatic film which shows good contrast and image quality. Figure 8 shows the poor quality of the color prints. These are results of errors that could have been avoided through the use of guidelines.

A local logging firm, Tree Farmers Inc., of Missoula, Montana, obtained small camera photography of clearcut logging blocks The purpose of the project was to calculate logging road mileage for a logging cost study. The photography was secured in early Spring before the winter snow had melted. This snow cover prevented accurate location of the road system within the logging blocks. However, the roads were easily delineated in uncut or partially cut areas. Planning could have made this a more successful project. Figure 9 is an

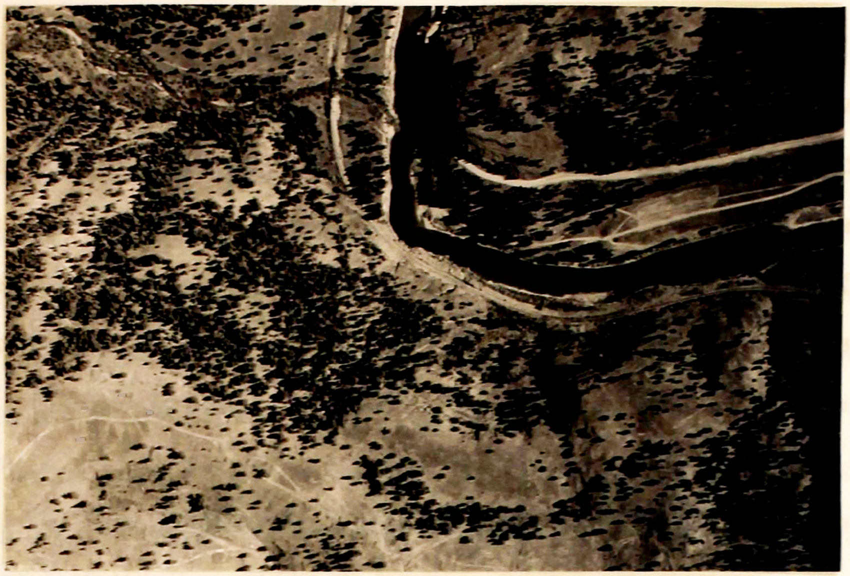


Figure 7. 35-mm panchromatic aerial photograph obtained with a Leica camera and a 50-mm focal length lens. This illustrates acceptable contrast and image quality (38).

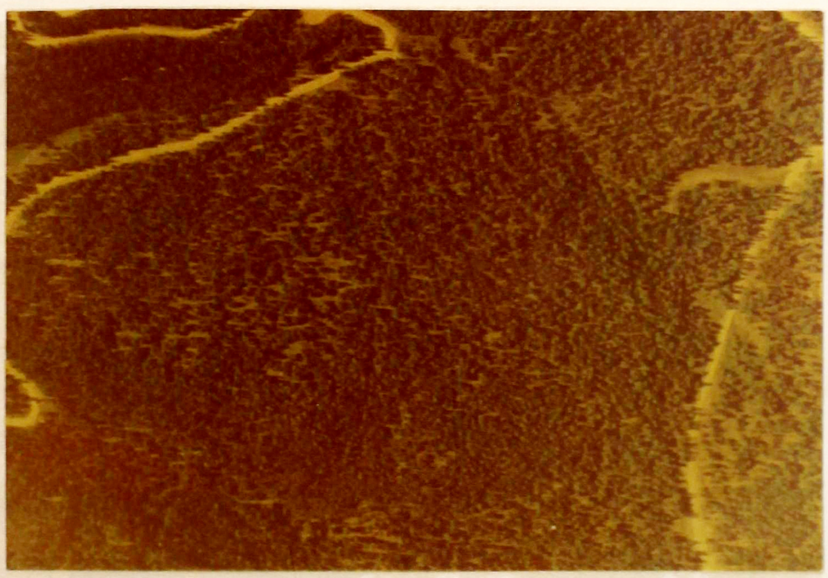


Figure 8. Print from color film exposed through a (K2) yellow filter. The yellow tone can be corrected slightly during the printing process, however, complete removal of this tone is not possible (38)

example of this photography.

A review of the literature has revealed the need and some of the solutions for obtaining information not provided by existing conventional aerial photography. Little has been published that provides, in one place, the information necessary for successful acquisition of small camera photography. Research at the University of Montana has provided considerable insight concerning the problems in securing small camera photographic coverage. The following section is a guide resulting from a combination of the literature reviewed and experience acquired at the University of Montana School of Forestry. To a large extent this section is an adaptation of conventional aerial photographic methods to small camera photography.

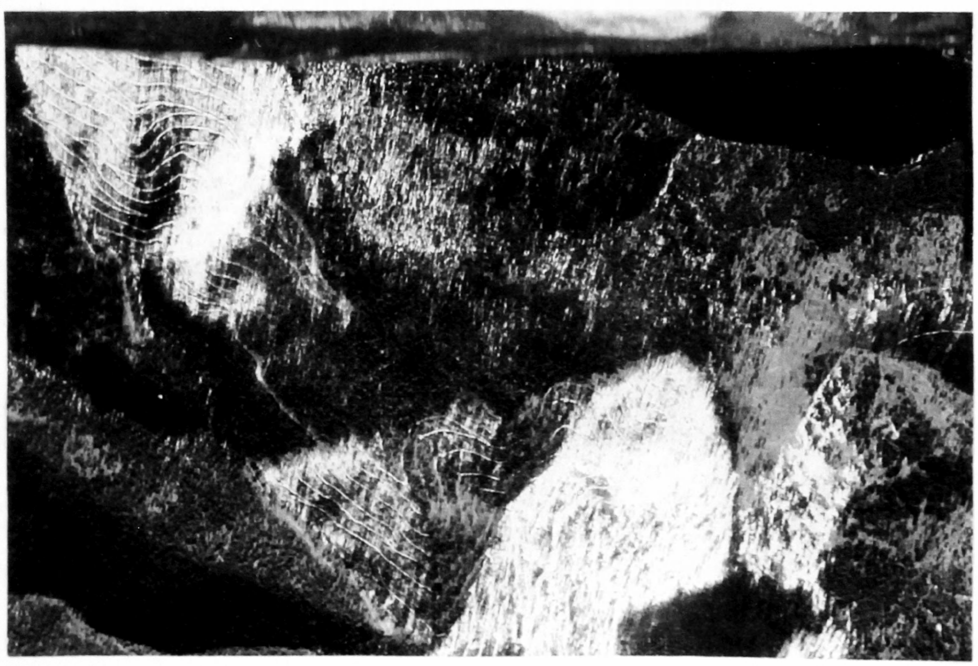


Figure 9. Aerial photograph taken of logging areas for the purpose of calculating logging road mileage. Note that a portion of the airplane is included in the picture, a problem inherent in exposing out the window of the airplane (39).

GUIDE FOR SMALL CAMERA AERIAL PHOTOGRAPHY

When planning a small camera photographic mission, it must be understood that the photographs obtained will not replace conventional aerial photography in terms of precision or quality. Although they are obtained in basically the same manner and contain essentially the same information, high precision and high quality results are not probable. Their value lies in being able to obtain them quickly, at a minimum cost for experiments or to derive useful infromation. When precision and quality are not important, small camera photography may provide the final answer.

There are seven basic considerations when planning and executing an aerial photographic mission. They are: 1) flight planning 2) flight procedure 3) post-flight procedure 4) aircraft 5) camera and lens 6) film and 7) filter. The following section is a guide for those who wish to take small camera photography. It is a guide because each mission is unique and demands latitude in the methods used.

Flight Planning

Flight planning for a small camera photographic mission is the same as for a conventional aerial photographic mission. The following method of flight planning has been adapted from a conventional photographic flight plan outlined by Avery and Meyer (6).

The following basic information must be obtained:

Scale of base map

Size of area to be photographed
Average ground elevation above sea level
Photo scale
  Print size and scale
  Enlargement factor
  Negative scale
Average endlap
Average sidelap
Negative format
Lens focal length
Aircraft ground speed

With this basic information at hand, the following calculations are necessary:

1. Flying height above ground and altitude
2. Direction and number of flight lines
3. Ground distance between flight lines
4. Actual percent sidelap
5. Map distance between flight lines
6. Ground distance between exposures
7. Map distance between exposures
8. Number of exposures on each line and total number of exposures
9. Time interval between exposures

A typical small camera flight plan is presented here to illustrate the calculations. A 35-mm camera with a 50-mm focal length lens is used with a Cessna 180 airplane as the camera platform. Two film types (panchromatic black and white and color) are used to obtain duplicate coverage of an area two miles wide and four miles long. The flight is planned, using a United States Geological Survey 7½ minute quadrangle map (inside back cover). This type of map is recommended because of its accuracy. The contour lines make it easier to choose ground control. Any map can be used, but the more terrain information available on the map, the easier it is to control the flight lines.

Ground targets can be established for flight line control and for cartographic control on the resulting photography. Figure 22 in the appendix give the recommended target arrays and their dimensions.

Basic Information

Base map scale - 1:24,000 or 1" = 2,000'
Average ground elevation above sea level - 4,600'
Size of area - 2 miles E-W by 4 miles N-S or
10,560' by 21,120'
Desired endlap - 60%
Desired sidelap - 30%
Desired print size - 5" by 7"
Desired print scale - 1:12,000
Negative format - 24 by 36mm or .079' by .118'
Lens focal length - 50-mm or .164'
Aircraft ground speed - 90 mph or 132 feet per second

Calculations (Refer to map inside back cover)

1. Flying height above ground (H) and altitude above sea level (A). (Figure 10 illustrates the relationship between flying height and scale.)

Enlargement factor (E) = 25.4mm/inch times length of long side of print in inches divided by the long side of the negative in mm. (30)

$$E = \frac{25.4 \text{ X } 7}{36}$$

E = 4.94

Negative scale reciprocal = scale denominator of print times enlargement factor

Negative scale reciprocal = 12,000 X 4.94 = 59,280

H = focal length (ft) times negative scale reciprocal

H = .164 X 59,280 = 9,722 feet

A = H + average ground elevation

A = 9,722 + 4,600 = 14,322 feet

2. Direction and number of flight lines

Direction - North-South (long dimension of the area)

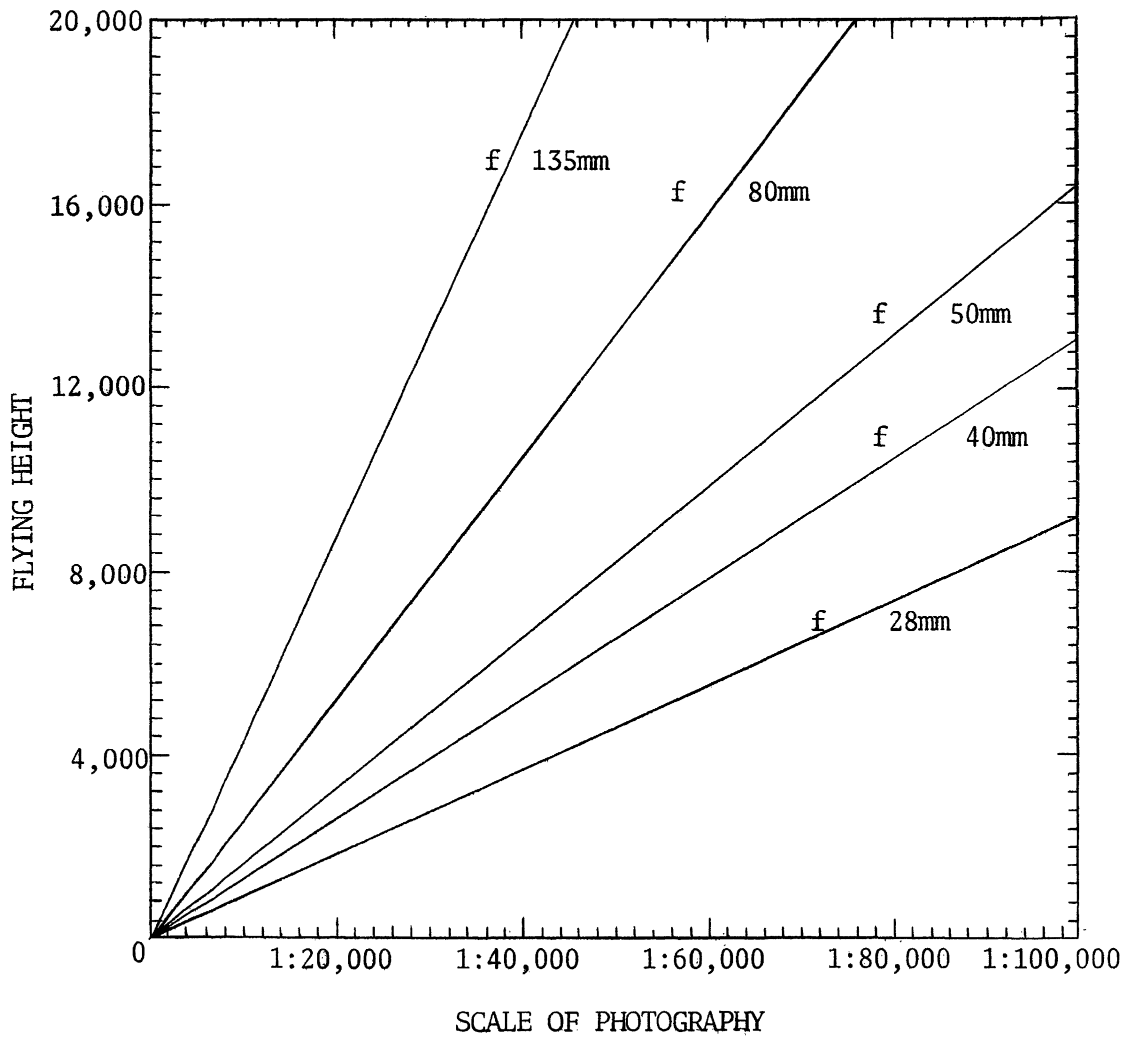


Figure 10. Relationship between flying height and scale for the common small camera focal length lenses.

Number of flight lines

With a sidelap of 30%, the lateral gain from one line to another is 70% of the negative width. The negative format is 24 X 36mm or .079' X .118'. At a negative scale of 1:59,280, the ground area included on the negative is 4,683' X 6,995'. If the camera is oriented so that the short dimension of the format is parallel to the direction of flight, there will be 4,896' between flight lines (6,995' X .70). (see map for illustration of format orientation) The number of intervals between lines equals the tract width divided by the distance between lines.

$$\text{Interval} = \frac{10,560}{4,896} = 2.15 \text{ or } 3 \text{ flight lines}$$

3. Ground distance (GD) between flight lines[1]

GD = tract width divided by number of intervals
GD = 10,560 / 2
GD = 5,280 feet

4. Actual percent sidelap

$$\text{Sidelap \%} = \frac{\text{Negative width coverage (ft)} - \text{GD (ft)}}{\text{Negative width coverage (ft)}} \times 100$$

$$\text{Sidelap \%} = \frac{6,995 - 5,280}{6,995} \times 100 = 24.5$$

5. Map distance between flight lines (map scale = 2,000' per inch)

$$\frac{1}{2,000} = \frac{X}{5,280}$$

X = 2.64 " between flight lines on the map

6. Ground distance between exposures on each line

Assume an average endlap of 60%. The gain from one exposure to the next is 40% of the width of the negative coverage. Therefore:

.40 X 4,683 = 1,873 feet

---

[1]It is not necessary to change the flight line separation for stereo-coverage of this area. However, the planner desired to place a flight line on each boundary of the area.

7. Map distance between exposures on each line.

$$\frac{X}{1,873} = \frac{1}{2,000}$$

X = 0.94 inches between exposures on the map

8. Number of exposures on each line.

$$\text{Interval between exposures} = \frac{\text{Tract length}}{\text{Ground dist. between exposures}}$$

$$\text{Interval} = \frac{21,120}{1,873}$$

$$\text{Interval} = 11.3$$

It will be necessary to take 12 exposures inside the tract plus two exposures at the end of each line or a total of 16 exposures per line to insure complete coverage.

9. Time interval between exposures.

$$\text{Time interval (seconds)} = \frac{\text{Ground distance between exp.}}{\text{Ground speed (ft. per second)}}$$

$$\text{Time interval} = \frac{1,873}{132} = 14.2 \text{ seconds}$$

Once the above information is obtained it should be recorded in an easy to read form for reference during the mission. Page 21 is a flight plan form with the necessary information entered for the above planned mission. Columns 12 and 14 will be filled during the mission once the light conditions have been determined. It may be necessary to change columns 10, 11 and 13 during the flight. This is discussed later under flight procedures.

Whether many flights are planned or only one, it is a good practice to record pre-flight, flight and post-flight data for possible future reference. Pages 74, 75 and 76 in the appendix are sample forms on which this data can be conveniently posted.

Figure 11

FLIGHT PLAN

Project Goose Rock Flat   Date 7/16/68   Time 10:00 A.M.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Strip No.	Film Type	Filter Type	ASA	Camera	Scale (RF)	Focal Length	Flying Height	True Altitude	True Air Speed	Exposure Interval (sec.)	Light Value	Shutter Speed	Aperture	Remarks
1 North	Pan-X	K2	32	Leica	1:59,280	50mm	9,722	14,322	90 MPH	14.2		1/250		
2 South	"	"	"	"	"	"	"	"	"	"		"		
3 North	"	"	"	"	"	"	"	"	"	"		"		
4 North	Koda-color X	Haze 1	64	Leica	"	"	"	"	"	"		"		
5 South	"	"	"	"	"	"	"	"	"	"		"		
6 North	"	"	"	"	"	"	"	"	"	"		"		

Table 1 presents flight data for use with a 35-mm camera and a 50-mm focal length lens. Tables 2 and 3 give the same information for a $2\frac{1}{4} \times 2\frac{1}{4}$ inch camera with an 50-mm and 80-mm focal length lens respectively.

If the angle of the elevation of the sun is such that a portion of the suns rays are reflected back toward the sun through the camera station, a hotspot or no-shadow point will appear on the resulting photography (21). Figure 12 illustrates this condition. A hotspot is a portion of the photographic image which is very light and overexposed. The relief displacement of the objects at this point exactly match the shadows and as a result no shadows are visible (29). The lack of shadows produces a washed out appearance in the images. The hotspot can cause the loss of approximately three percent of the stereoscopic model for mapping and photo-interpretation work (29).

According to Mason (21), the hotspot will always occur when the sun's angle of elevation is equal to or greater than the tangent of the focal length of the lens divided by one half the length of the shortest dimension of the format.

$$\text{Tangent of sun's angle of elev.} = \frac{\text{Focal length}}{\frac{\text{short dimension of format}}{2}}$$

Under these conditions the hotspot is always on the photograph, but it is not always apparent. Its appearance seems to depend on atmospheric conditions and the cover of the area photographed.

Using a 50-mm lens and a $2\frac{1}{4} \times 2\frac{1}{4}$ inch format, the hotspot will be present when the sun is bright and its elevation is $60^{\circ}\ 10'$ or

Table 1. Flight Data for 35-MM Cameras with 50-MM Focal Length Lens

Negative Scale Recip-rocal	5" X 7" Print Scale Recip.	Print Scale (ft/in)	Flying Height (feet)	Strip Separation 30% Sidelap (feet)	Exposure Separation 60% Endlap (feet)	Negative Coverage (feet)	Interval in Seconds Between Exposures to Achieve 60 Percent Endlap*						
							80 MPH	90 MPH	100 MPH	110 MPH	120 MPH	130 MPH	140 MPH
39,125	7,920	660	6,416	3,232* 2,164	1,236* 1,847	3,091 X 4,617	11 16	9 14	8 13	8 11	7 11	6 10	6 9
47,424	9,600	800	7,778	3,917 2,622	1,498 2,238	3,746 X 5,596	13 19	11 17	10 15	9 14	9 13	8 12	7 11
49,400	10,000	833	8,102	4,080 2,731	1,561 2,332	3,902 X 5,829	13 20	12 18	11 15	10 14	9 13	8 12	8 11
59,280	12,000	1,000	9,722	4,896 3,278	1,873 2,798	4,683 X 6,995	16 24	14 21	14 19	12 17	11 16	10 15	9 14
78,250	15,840	1,320	12,833	5,764 4,327	2,473 3,694	6,182 X 9,234	21 32	19 28	17 25	15 23	14 21	13 19	12 18
98,800	20,000	1,667	16,203	8,161 5,463	3,122 4,663	7,805 X 11,658	27 40	24 35	21 32	19 29	18 26	16 24	15 23

* Top figures are for a camera oriented with the short dimension of the format in the direction of flight. Bottom figures are for a camera oriented with the long dimension of the format in the direction of flight.

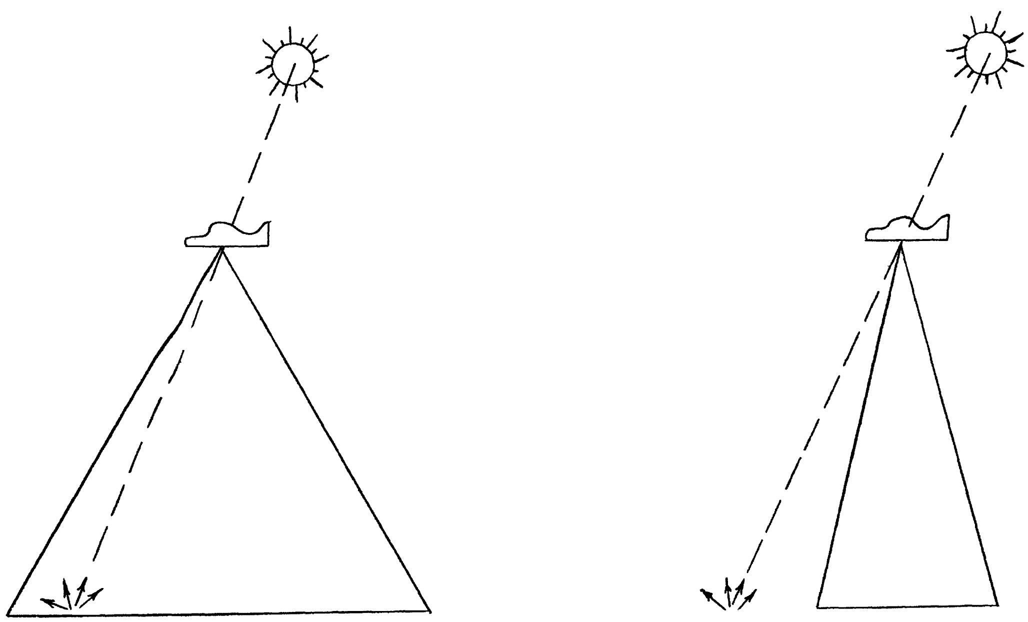
Table 2. Flight Data for 2¼ X 2¼ inch Cameras with 50-MM Focal Length Lens

Negative Scale Recip-rocal	2X Print Scale Recip.	Print Scale (ft/in)	Flying Height (feet)	Strip Separation 30% Sidelap (feet)	Exposure Separation 60% Endlap (feet)	Negative Coverage (feet)	Interval in Seconds Between Exposures to Achieve 60 Percent Endlap						
							80 MPH	90 MPH	100 MPH	110 MPH	120 MPH	130 MPH	140 MPH
15,840	7,920	660	2,598	2,079	1,188	2,970 X 2,970	10	9	8	7	7	6	5
19,200	9,600	800	3,149	2,520	1,440	3,600 X 3,600	12	11	10	9	8	8	7
20,000	10,000	833	3,280	2,625	1,500	3,750 X 3,750	13	11	10	9	9	8	7
24,000	12,000	1,000	3,936	3,150	1,800	4,500 X 4,500	15	14	12	11	10	9	9
31,680	15,840	1,320	5,196	4,158	2,376	5,940 X 5,940	20	17	16	15	14	12	12
40,000	20,000	1,667	6,560	5,250	3,000	7,500 X 7,500	26	23	20	19	17	16	14
60,000	30,000	2,500	9,840	7,875	4,500	11,250 X 11,250	38	34	31	27	26	24	22
80,000	40,000	3,333	13,120	10,500	6,000	15,000 X 15,000	51	45	41	37	34	31	29

Table 3. Flight Data for 2¼ X 2¼ inch Cameras with 80-MM Focal Length Lens

Negative Scale Recip-rocal	2X Print Scale Recip.	Print Scale (ft/in),	Flying Height (feet)	Strip Separation 30% Sidelap (feet)	Exposure Separation 60% Endlap (feet)	Negative Coverage (feet)	Interval in Seconds Between Exposures to Achieve 60 Percent Endlap						
							80 MPH	90 MPH	100 MPH	110 MPH	120 MPH	130 MPH	140 MPH
15,840	7,920	660	4,150	2,079	1,188	2,970 X 2,970	10	9	8	7	7	6	5
19,200	9,600	800	5,030	2,520	1,440	3,600 X 3,600	12	11	10	9	8	8	7
20,000	10,000	833	5,240	2,625	1,500	3,750 X 3,750	13	11	10	9	9	8	7
24,000	12,000	1,000	6,288	3,150	1,800	4,500 X 4,500	15	14	12	11	10	9	9
31,680	15,840	1,320	8,300	3,880	2,376	5,940 X 5,940	20	17	16	15	14	12	12
40,000	20,000	1,667	10,480	5,250	3,000	7,500 X 7,500	26	23	20	19	17	16	14
60,000	30,000	2,500	15,720	7,875	4,500	11,250 X 11,250	38	34	31	27	26	24	22

greater. Similarly, a 50-mm lens with a 24 x 36-mm format, the hotspot will be present when the elevation of the sun is 76° 02' or greater. At latitudes of 45 degrees north or more, the sun's elevation never is greater than 68° 30', therefore the hotspot is not a problem with 35-mm cameras and a 50-mm focal length lens.



Hotspot
50-mm focal length, 2¼ X 2¼ inch format, June 26, 1968 12:00 noon, sun's elevation 65° 14'

Hotspot
50-mm focal length, 24 X 36-mm format, June 26, 1968, 12:00 noon, sun's elevation - 65° 14'

Figure 12. Hotspot position in relation to format size (21).

The hotspot can be avoided by planning the flight to avoid the time of day (late morning or early afternoon hours) when the suns elevation is equal to or greater than that calculated for the particular lens focal length and format used.

The panchromatic photography in figure 5 was obtained at 46 degrees North latitude in July between 10:00 am and 12:00 am. A hotspot appears on the lower left portion of the print. If the photography had been taken a little later, when the elevation of the sun was higher, the hotspot would have appeared closer to the left center of the print. A hotspot in that position would seriously effect the stereoscopic model. Appendix B presents a method of calculating the elevation of the sun for a specific time and place.

Flight Procedures

After the flight is planned and arrangements made for the airplane, two things are necessary. First the photographer must be thoroughly familiar with the camera and equipment and be sure that it is all there when he boards the airplane. Secondly, the pilot must be thoroughly briefed so that he knows exactly what is planned and what is expected of him.

Prior to take-off, the photographer must meet with the pilot and explain the flight plan in detail. The flight map should be used to point out the planned flight lines and the ground control.

Also important is the necessity to maintain true altitude and true airspeed during the period when the photographs are being taken.

The altimeter and airspeed indicator in an airplane are instruments which measure pressure and convert it to altitude and airspeed. Both instruments are calibrated to give correct readings in the environment of a standard atmosphere. (A standard atmosphere is based on a sea level pressure of 29.92 inches of mercury at 59 degrees F. and a normal temperature lapse rate of 3.3 degrees F. per 1,000 feet increase in elevation and a pressure lapse rate of approximately one inch of mercury per 1,000 feet increase in elevation) (8). Any variation from the standard atmosphere and the instruments give incorrect readings. Seldom is the atmosphere a standard one and therefore the instrument readings must be corrected for this variation. The pilot can easily and quickly do this with his navigational computer. True altitude and true airspeed must be calculated if agreement with the planned altitude and airspeed is expected.

If possible, exposure interval should be computed according to the ground speed of the airplane. Ground speed can be checked where distances between natural or manmade terrain features are known. Simply record the time taken to travel between two points of known distance and compute the ground speed using the formula:

$$\text{Velocity} = \frac{\text{Distance}}{\text{Time}}$$

For example, if the distance between two landmarks is determined to be 1.5 miles (7,920 feet) and it takes 50 seconds to travel between the two points, the ground speed is computed as follows:

$$\text{Velocity} = \frac{7{,}920}{50} = 158.4 \text{ feet/second} = 108 \text{ mph.}$$

Assume that because of variation from standard conditions, the airspeed indicator shows 88 mph. If the desired ground speed is 100 mph, the correct indicated airspeed to fly can be computed as a simple proportion.

$$\frac{\text{Correct indicated airspeed}}{\text{Desired ground speed}} = \frac{\text{Indicated airspeed}}{\text{Computed ground speed}}$$

$$\frac{X}{100} = \frac{88}{108}$$

$$X = 81.5 \text{ mph}$$

Ground speed checks should be made as near the area to be photographed as possible and in the direction of the planned flight lines. This way any head or tailwinds will be accounted for.

A trial run should be made before photography begins. During this trial run, the pilot and photographer can identify ground control, the pilot can compute the necessary corrections for the instrument readings based on air and wind conditions over the area and the photographer can obtain light meter readings for determining exposure. Also, it may be necessary to adjust the exposure interval to fit the conditions indicated during the trial run. If crosswinds make it necessary to crab the airplane, the camera must be oriented to compensate for this. The amount of crab should be estimated during the trial run so that the camera can be properly oriented. The camera in figure 13 is oriented to correct for an airplane that is crabbed to the right.

After all adjustments have been made for the prevailing conditions, the photography can begin. The pilot, or if possible a third person acting as timer-navigator, determines when the airplan has reached the starting point and signals the photographer to expose the first frame by calling out 'one'. To avoid mistakes, the signal should be made by calling out the number of the exposure loud enough to override the airplane noise. If an intercommunication system is available, it should be used to insure that exposure signals are not missed.

Figure 13. Photographer using a porthole in a Cessna 206. A seat has been removed to expose the porthole. The position of the camera indicates correction for crab (37)

The exposure interval can be timed better by using a stop watch, but an ordinary wrist watch with a second hand will work.

Post-Flight Procedure

Once the photography has been completed, notes should be recorded concerning light conditions, f/stop, shutter speed, haze conditions and any unscheduled events that might have altered the original flight plan. Form 3, page 76 is a sample form for recording this information.

The prints or transparencies should be layed out and exposure number and flight line number indicated on each one. At this time, it can be determined if the desired coverage was obtained, crab can be analyzed and image quality evaluated. A critical assessment of the results should lead to improved future flights.

Aircraft

When choosing an airplane, ceiling and design must be considered. The airplane must be able to operate at an altitude that is sufficient to obtain the negative scale. For example, assume that a 5 X 7 inch print with a scale of 1:15,840 is desired. Using a 50-mm focal length lens, it will be necessary to fly at a height of 12,833 feet above the average ground elevation. (Refer to page 17 for the method of calculating flying height.) If the ground elevation is 3,000 feet above sea level, the true altitude of the plane will be 15,833 feet. The airplane chosen for this mission, then, must be capable of and equipped for operation at this altitude. If the plane is rented, the flying service can provide information concerning the operational ceiling of the aircraft. This information can also be obtained from brochures or manuals usually available at the flying service. In all cases, the pilot should know the operational limitations of his aircraft.

For aerial photo missions at high altitudes, the lack of sufficient oxygen for breathing becomes a problem. The Manual of Color Aerial Photography (1) states that oxygen is recommended at elevations above 10,000 feet and is an absolute necessity at 15,000 feet above mean sea level. Each individual differs in his tolerance to oxygen deficiency, but the effects can be generalized as follows:

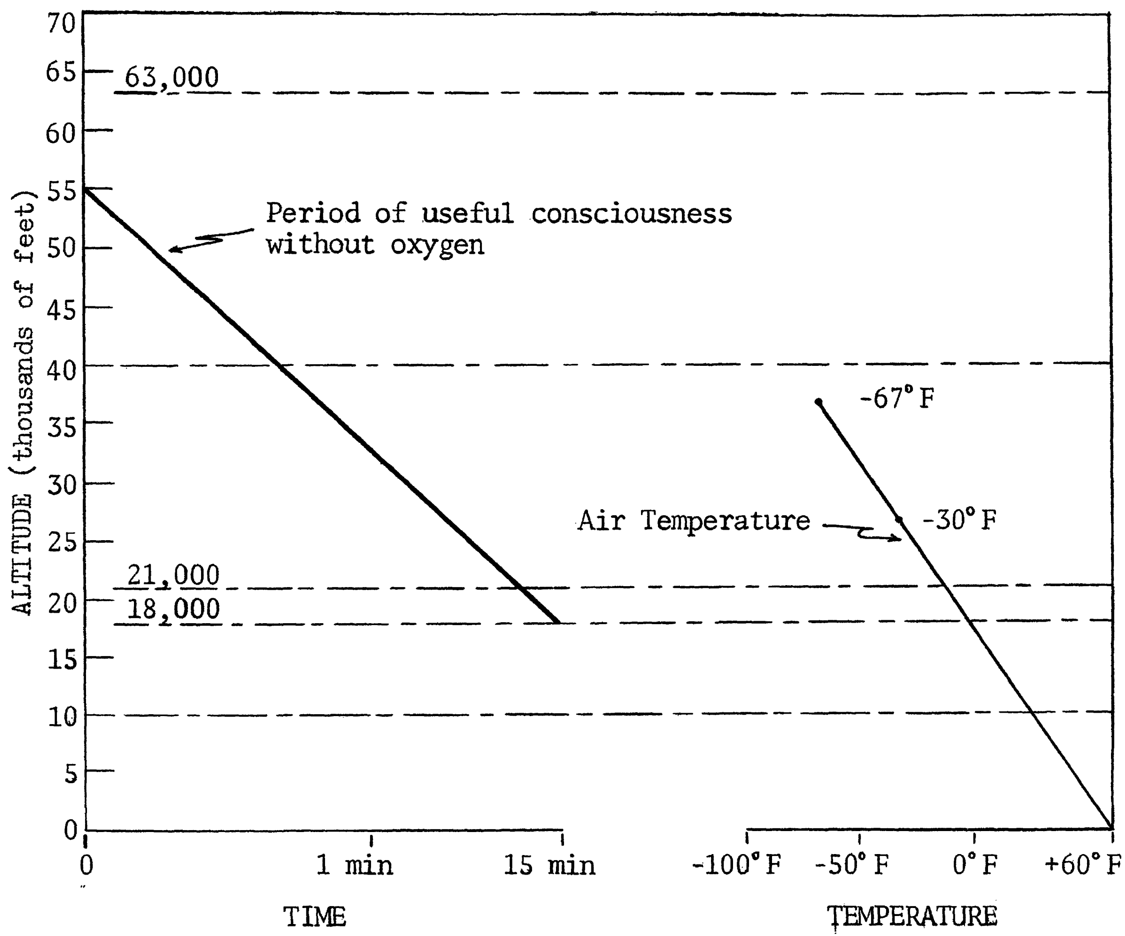


Figure 14. Sketch showing the various effects of altitude (1). Air Force regulations require the use of oxygen in unpressurized aircraft at 10,000 feet. People live at 18,000 feet in the Andes Mountains. A candle will not burn above 21,000 feet. Man's oxygen ceiling is at 40,000 feet--above this altitude oxygen under pressure is needed. Blood boils at body temperature at 63,000 feet.

At 8,000 to 10,000 feet for over 4 hours the airman experiences fatigue and sluggishness.

At 10,000 to 15,000 feet for two hours or less the airman experiences fatigue, drowsiness, headache and poor judgement.

At 15,000 to 18,000 feet for one hour or less the airman experiences false sense of well being, over confidence, faulty reasoning, narrowing of field of attention, unsteady muscle control, blurring of vision, poor memory and may pass out.

Over 18,000 feet the above symptoms come much faster and they may be accompanied by loss of ability to reason, repeated purposeless movements, fits of laughing, crying or other emotional outbursts.

Loss of consciousness generally occurs at 26,000 feet in 4 to 6 minutes, at 30,000 feet in 1 to 2 minutes, at 38,000 feet in 30 seconds or less and above 50,000 feet in about 10 seconds (1)

Figure 14 shows the various effects of altitude.

The airplane chosen must provide an unobstructed opening through which the photographs can be taken. Airplanes with an overhead wing and a baggage or rear seat passenger door meet this requirement. Some low winged airplanes have a baggage door located behind the wing which provides a satisfactory opening for obtaining small camera photography. Figure 15 illustrates a photographer using the baggage door of a Cessna 180.

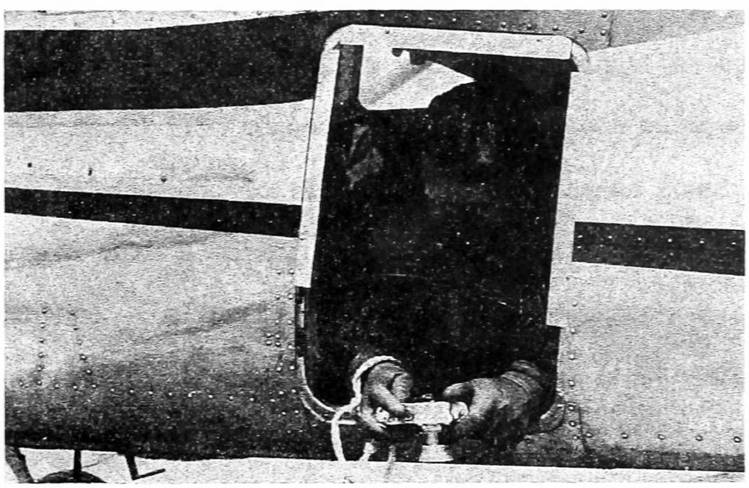


Figure 15. Photographer using the baggage door of a Cessna 180. Note the plexiglass cover fashioned for protection of the photographer (37).

If considerable photography is anticipated and a company or privately owned plane is available, it may be possible to cut a porthole in the bottom of the plane. The use of a porthole cuts down on cabin noise and is usually more comfortable for the photographer. Figure 13 illustrates a photographer using a porthole in the bottom of a Cessna 206. When the plane is used for other than photographic missions, the porthole is covered.

It is not recommended that vertical aerial photography be attempted out of an open window, because a portion of the airplane is usually imaged on the resulting photography. Figure 9 illustrates this problem.

Camera and Lens

Any 35-mm or 2¼ X 2¼ inch camera with a good quality lens can be used. However, since it is necessary to expose in rapid succession to obtain stereo-coverage, it is recommended that the camera be equipped with a rapid film advance lever. There are also cameras available that have automatic film advance mechanisms powered either with batteries or with a spring mechanism. Either of these types have the advantage of allowing more time for the photographer to level the camera and adjust for crab. However, a camera without a rapid film advance lever can be used when exposure intervals are longer.

The film must be advanced and the camera oriented and leveled during the interval between exposures. This can be done by an experienced cameraman for intervals as short as five seconds, however for the inexperienced, intervals of ten seconds or more are recommended. Tables 1, 2, and 3 indicate the exposure interval necessary to obtain sixty percent endlap.

Listed in table 4 are some of the available 35-mm and 2¼ X 2¼ inch cameras that could be used. The list is not necessarily a recommendation for those cameras, nor is it a complete listing. It indicates however, a few of the many cameras that would produce satisfactory small camera vertical aerial photographs.

The type of viewing system employed on the camera is not important. Normally the photographer does not have time to view the scene before exposure.

There are two types of shutters used on modern small cameras. They are the diaphragm or leaf type and the focal-plane shutters. Either type is satisfactory for small camera photography. The diaphragm shutter is normally located between the lens elements, although in some cameras it is behind the lens. It consists of a ring of overlapping metal blades, usually three to five, which normally are closed to block the light but open when released to permit the light to pass through for a precise amount of time (24). It has the characteristic of admitting light to all parts of the negative at the instant it is opened and cutting off all light at the instant it closes (2). In aerial mapping cameras, this characteristic is important because it makes it possible to preserve the correct relationship of all object points photographed on the negative (2).

The focal-plane shutter, as the name implies, lies close to the focal plane of the camera. Older shutters of this type consisted of a cloth curtain slightly longer than twice the length of the format

SINGLE LENS REFLEX CAMERAS

CAMERA	STANDARD LENS	SHUTTER (Type & Range)
Bessler Topcon Super D	f/1.4 or f/1.8 58-mm	Cloth Focal-Plane 1-1/1000 sec.
Minolta SR-T 101	f/1.4 58-mm or f/1.7 55-mm	Cloth Focal-Plane 1-1/1000 sec.
Miranda FVT,GT	f/1.9 50-mm	Cloth Focal-Plane 1-1/1000 sec.
Canon FT-QL, T1-QL	f/1.8 50-mm	Cloth Focal-Plane FT, 1-1/1000 sec. TL, 1-1/500 sec.
Leicaflex SL	f/2.0 50-mm	Cloth Focal-Plane 1-1/2000 sec.
Nikon F Photomic TN	f/1.4 50-mm f/2.0 50-mm f/1.2 55-mm	Metal Focal-Plane 1-1/1000 sec.
Exakta VX 1000	f/1.9 or f/2.0 50-mm	Cloth Focal-Plane ½-1/1000 sec.
Honeywell Pentax H3v	f/1.8 55-mm	Cloth Focal-Plane 1-1/1000 sec.
Bessler Topcon Auto 100	f/2.0 53-mm	Leaf Behind-Lens 1-1/500 sec.
Kodak Retina Reflex IV	f/1.9 or f/2.8 50-mm	Leaf Behind-Lens 1-1/500 sec.
Leica M-4	f/1.4 50-mm f/2.0 50-mm f/2.8 50-mm	Cloth Focal-Plane 1-1/1000 sec.
Bronica C 2¼ X 2¼	f/2.8 75-mm	Cloth Focal-Plane 1-1/500 sec.
Hasselblad 500C 2¼ X 2¼	f/2.8 80-mm	Leaf Between-Lens 1-1/500 sec.
(Honeywell) Rolleiflex SL66 2¼ X 2¼	f/2.8 80-mm	Cloth Focal-Plane 1-1/1000 sec.

Table 4. Typical cameras that are available and their standard lens and shutter type (22).

and slightly wider. Slits of varying widths at various intervals, each representing a specific speed, are cut across the narrow dimension of the curtain. When the shutter is released a slit travels across the frame and exposes a portion of the negative at a time. The curtain is wound on rollers at the side of the format against a spring tension which is the driving force of the shutter (2).

Modern focal-plane shutters in small cameras consist of two curtains, either metal or cloth, one which travels across the frame and the other which follows at a definite interval. The width of the slit that admits light is determined by the interval between the curtains (24). This type of shutter makes it possible to obtain faster shutter speeds. Some 35-mm cameras with focal-plane shutters are capable of speeds of up to 1/2,000th of a second (24).

The use of the focal-plane shutter in aerial mapping cameras is unsatisfactory because it introduces positional errors in the relationship of the photographed images (2). That is, the position of the objects photographed as the slit starts across the negative will be in error in relation to the objects photographed at the other side of the negative due to the movement of the camera through the air during exposure.

The amount of image motion can be controlled in small camera photography by using shutter speeds of at least 1/250th of a second, in combination with slow aircraft ground speeds. Image motion is dependent upon aircraft speed and shutter speed as well as the scale of photography. The amount of image motion can be calculated with the following formula:

$$M = \frac{1.467\ VT}{S}$$

where M is the image movement in inches, V is the ground speed of the airplane in miles per hour, T is the shutter speed in seconds and S is the scale of the photography in feet per inch (28). As an example consider a small camera mission, using a 50-mm focal length lens (1.97 inches), flying at a ground speed of 100 miles per hour(146.7 feet per second), 12,833 feet above ground (scale of 1:78,250 or 6,521 feet per inch on the negative) and exposing at 1/250th of a second. The image motion due to the aircraft speed would be .0001 inch. If the negative is enlarged to a scale of 1:15,840, the image motion would be .0005 inch. This amount of image motion is not significant to the user of parallax wedges and plastic templates. However, image motion can significantly reduce image quality, as photo scale increases and faster ground speeds are used.

A modern small camera is normally equipped with a lens of sufficient quality to produce good aerial photographs. Therefore, in purchasing a camera the main considerations are lens focal length and lens speed.

It has been determined mathematically, and from experience that the best lens focal length should be approximately equal to the diagonal of the format (24). Theoretically, 46-mm would be the best focal length for a 35-mm camera (24 X 36-mm format), however, standard lenses range from 50-mm to 58-mm. For a camera with a 2¼ X 2¼ inch format, 80-mm would be the best focal length and standard lenses for this type of camera range from 75-mm to 85-mm (24). In general, it is recommended that a standard focal length lens be used for obtaining small camera vertical aerial photography. Lenses with shorter focal lengths (wide-angle) or longer focal lengths (tele-photo) may be desirable depending on the purpose of the photography. Table 5 gives the focal lengths of lenses for various film formats.

Lens speed or relative aperture is the ratio of the focal length to the diameter of the camera diaphragm at its largest opening, and is expressed as an f/number or f/stop. A lens with an indicated speed of f/2 means that the diameter of the largest diaphragm opening is ½ of the lens focal length. For instance and f/2, 50-mm lens has a maximum opening of 25-mm. This indicates the amount of light that can enter the camera to expose the film. Any focal length lens set at f/2 will allow approximately the same amount of light to enter as a 50-mm, f/2 lens (24).

The effective aperture or f/stop value, is regulated by the iris diaphragm of the lens. Each full f/stop doubles or halves the amount of light that can enter and expose the film. Most modern cameras have the following full f/stop values: 22,16,11,8,5.6,4,2.8,2,1.8, and 1.0 (24). To"stop down" the aperture, a change from f/8 to f/11 halves the amount of light that reaches the film and conversely, going from an f/11 to an f/8 doubles the light.

For small camera photography it is desirable to have a lens with a speed of f/2 or faster in order to allow exposure latitude when photographing in less than ideal light conditions.

Table 5
FOCAL LENGTHS OF LENSES FOR VARIOUS FILM FORMATS (24)

Film sizes in inches	Best focal length	Focal length commonly used
3/4 X 1 (single frame 35-mm)	31mm	35mm-40mm
1 X 1½ (double frame 35-mm)	46mm	50mm-58mm
2¼ X 2¼	80mm	75mm-85mm
2¼ X 3¼	100mm	100mm-105mm
3¼ X 4¼	130mm	125mm-135mm
4 X 5	163mm	150mm-165mm
5 X 7	218mm	200mm-220mm
8 X 10	325mm	300mm-380mm

To insure that a near vertical photograph is obtained, a leveling device must be attached to all small cameras. A bulls-eye level is generally available and can be easily attached to the camera. To attach the level to the camera, it will be necessary to assume that the lens is attached to the camera body in a true perpendicular relationship. Choose a table top or other flat surface that can be leveled with a carpenters level, and set the camera on its lens. The bulls-eye level is then positioned on the back of the camera so that the bubble is centered and the level attached with masking or glass tape. The backs of some cameras may require a small shim on one side of the level before taping it down. It is a good practice to check the level before each mission. Figure 13 illustrates a Hasselblad 500C with the level attached.

Film

The resource manager has a choice of four main film types. These are based on the color sensitivity of the film and include: panchromatic black and white, infrared black and white, color and infrared color. His choice should reflect the objectives of the projects, therefore a knowledge of film characteristics is essential. With an understanding of film, tests can be conducted to determine the film that will best satisfy the objectives.

Panchromatic black and white film. Panchromatic black and white film is sensitive to the visible portion of the electromagnetic spectrum (figure 16). Objects are recorded in shades of gray, depending upon the light reflectance of the object, the film sensitivity and filter used.

Aerial panchromatic film differs from small camera panchromatic film in two respects, film base and color sensitivity. Aerial films have extended sensitivity in the red portion of the spectrum, which tends to counteract the effects of atmospheric haze (figure 16). The film base of aerial films is designed to be dimensionally stable for the purpose of mapping (figure 17).

Panchromatic film is used extensively for topographic and planimetric mapping and for general interpretation work where the subject presents good contrast with its surroundings. It has also been used in combination with selected filters to increase subtle tonal differences for easier interpretation (25 & 30). (See page 52 for a discussion of filters and their use.) Table 6 lists some of the Kodak black and white films that can be utilized to obtain small camera photographs.

Infrared black and white film. Infrared black and white film is

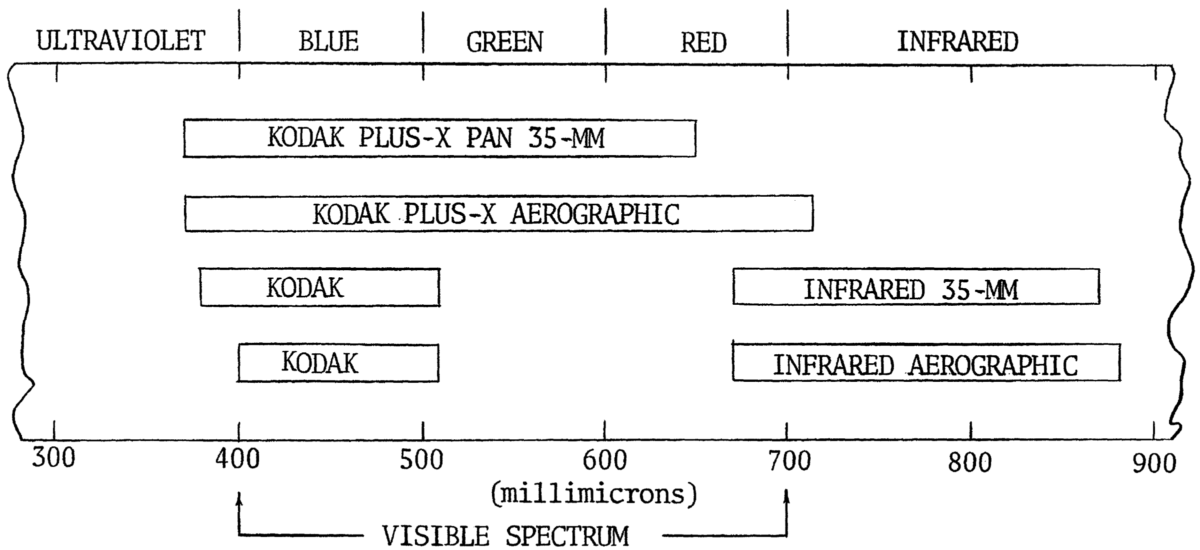
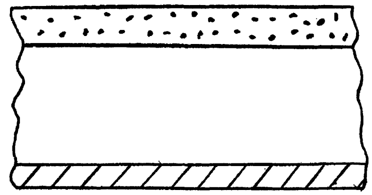


Figure 16. Schematic diagram of a portion of the electromagnetic spectrum illustrating the approximate spectral sensitivity of four black and white negative films. Infrared Aerographic has some sensitivity to all portions of the visible spectrum. Note the extended red sensitivity of Plus-X Aerographic.

Figure 17. Cross section of a black and white panchromatic film (5).



sensitive to a portion of the visible spectrum in the blue region and to red and infrared radiation (figure 16). On infrared prints, objects with high infrared reflectivity are recorded in light shades of gray, while objects with low infrared reflectivity are recorded in dark shades of gray or black.

Table 6. Kodak Black and White Negative Films (14)

Name	Speed (ASA)	Description
Plus-X Pan	125	Medium-speed, extremely fine grain with high definition.
Panatomic-X	32	Low-speed, extremely fine grain, moderate contrast.
Tri-X	400	High-speed, very fine grain.
Infrared	20 with a No. 25 (A) filter	Low-speed, moderately high contrase, infrared sensitive.
High Speed Infrared	50 with a No. 25 (A) filter	High-speed, available in 35-mm long rolls.

Infrared film is available in 35-mm size (table 6). Its color sensitivity is almost identical to that of aerial infrared film (figure 16). However, the base of the aerial film is more stable to permit accurate mapping.

The fact that infrared black and white film is sensitive to a portion of the visible spectrum, requires that it be exposed through a filter which absorbs the visible light in order to obtain true infrared rendition (14). Normally a red (25A) filter is used for this purpose, as this allows only the red and infrared portion of the spectrum to be transmitted (figure 20). In forest survey work, a yellow (no.12-minus blue) filter is sometimes used to improve differentiation between tree species (14).

Infrared radiation is refracted less by camera lenses than visible radiation. Because of this the infrared image is formed behind the plane of best focus for visible rays, therefore the film to lens distance must be increased for photography with infrared film (2). Many camera lenses are marked on the focusing ring to indicate the necessary change. If this is not the case, a test should be conducted to determine the best focal position. As a basis for focus tests, extend the lens from a conventional focus setting by ¼ of 1 percent of the focal length of the lens (14).

Photo-electric light meters respond to visible light only (14), and the ratio of infrared radiation to visible radiation in sunlight is variable. Therefore, it is not possible to assign exact film speeds to infrared films. For best results, a test series of exposures should be made to determine the proper exposure.

Infrared radiation (in the near infrared spectrum) is scattered less by atmospheric haze than the shorter wave-length radiation (blue light) (2). This fact makes it possible to obtain aerial photography with infrared film when atmospheric haze would hamper other types of photography. When correctly exposed, infrared film produces good contrast between terrain features and water and between broadleaf plants and coniferous plants (14).

Color film. Color films produced for use in small and aerial cameras utilize the subtractive method to synthesize color. The dyes formed in the emulsion, after exposure and processing, subtract (absorb) a portion of the visible spectrum and transmit the remaining portion, reproducing the color photographed (24).

Color films are multilayer emulsions (figure 18), three of which are sensitive to either blue, green or red light (figure 19). These three layers contain color formers for yellow, magenta and cyan dye. In addition to the light sensitive layers, the film may have a thin gelatin layer on top as a protective coating, a yellow-absorbing filter layer on top of the green-sensitive layer which prevents blue light from penetrating to the middle and bottom layers, a gel separator between the green and red sensitive layers and an inert gelatin backing to prevent curling. This backing usually contains dyes to prevent halation, which is the spreading of a photographic image beyond its proper boundaries (24).

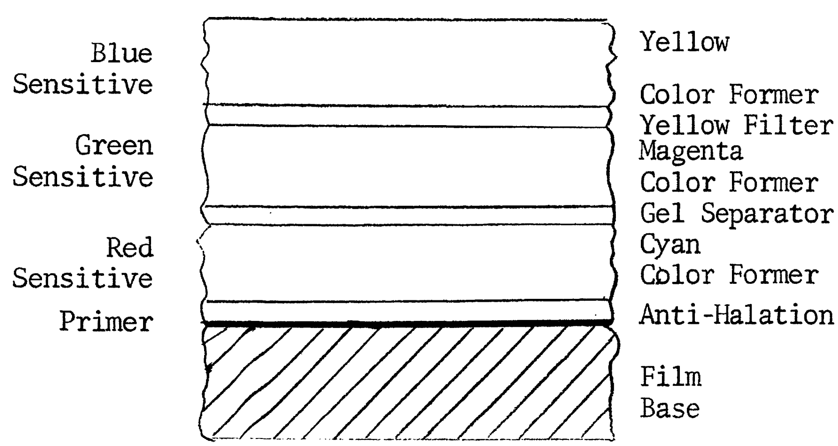


Figure 18. Cross Section of a reversal color film (1).

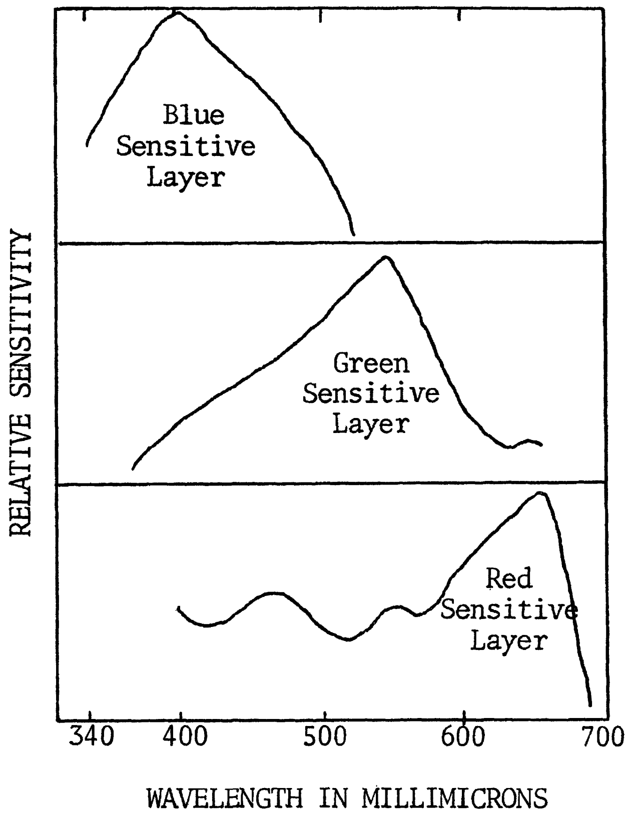


Figure 19. Spectral Sensitivity of a typical color transparency film (1).

The reproduction of color is based on the fact that white light is made up of three basic or primary colors: red, green and blue. By mixing (adding) these colors in various amounts, it is possible to reproduce almost any desired color. These three colors are called additive primaries, because they must be added together to match other colors.

When two of the additive primaries are combined, a new color is produced. This new color is essentially white light minus one of the additive primaries, and it is called a subtractive primary. There are three subtractive primaries and they are called cyan, magenta and yellow. The additive and subtractive primaries are complementary colors as shown below:

Additive Primary		Subtractive Primary
Red	white minus red	Cyan
Green	white minus green	Magenta
Blue	white minus blue	Yellow (24)

Objects appear colored to the human eye because they absorb and reflect portions of the white light that illuminates them. For example, when color film is used to photograph a tomato, the magenta and yellow dyes in the film absorb the green and blue components of white light and only the red is transmitted. This causes the tomato to appear red (24).

There are two types of color film available, one which is a reversal type producing a positive transparency slide and one which produces a color negative for the production of positive prints (either color or black and white).

Either of the two films produce good aerial photographs. The color transparency film requires that the photographs be projected using either the standard method of projecting to a screen in front of the projector or a rear projection system. This system utilizes a translucent screen with the projector behind the screen, projecting the images through the screen (30). An overhead projector can also be used, especially for mapping purposes. For stereo examination of transparency film, prints should be obtained.

Table 7 is a representative listing of daylight color negative films and table 8 lists some of the reversal color films available.

Table 7. Negative Color Films For Daylight (23).

Name	Speed (ASA)	Available Sizes
Dynachrome for color prints	64	35mm (20 exp.) 126 (12 & 20 exp.) 127, 120 620
Kodacolor-X	80	35mm (12, 20 exp.) 126 (12 & 20 exp.) 120, 127, 616, 620 828
Ektacolor Profession-al Type S	100	120,620,220

The greater dimensional stability of the aerial color film base is essentially the only difference between that and color film produced for small cameras.

Color film has its greatest utility where tonal differences are important. It has been used successfully for a number of forestry applications (7), photo-geologic interpretation (9) and interpretation of glaciated areas (34).

<u>Infrared Color Film</u>. Infrared color film is also a multilayer, reversal film. It differs from regular color film in that the blue sensitized layer is replaced with infrared sensitivity. The first or top layer is sensitive to green, the middle layer to red and the bottom layer to infrared radiation. Since all layers are sensitive to blue light and no yellow filter layer is incorporated within the film itself, it is necessary to expose through a yellow filter. When processed, a yellow positive image records in the green sensitive layer, a magenta image in the red sensitive layer, and a cyan image

Table 8
Transparency Color Films for Daylight

Name	Speed (ASA)	Available Sizes	Rendition
Agfachrome CT 18	50	35mm (20 and 36 exp.) 120, 127	Excellent reds; good blacks & golds; slightly warm whites and skys; slightly yellow greens over-all
Anscochrome 64	64	35mm (20 and 36 exp.) 120, 126 (20 exposure)	Slightly cool reds; good blacks; yellowish whites; slightly green sky; slightly warm, yellowish greens
Anscochrome 100	100	35mm (20 exp.)	Good reds, golds and blacks; slight yellowish whites; weak blue sky; slightly warm yellow-brown cast in greens
Dynachrome 25	25	35mm (20 and 36 exp.)	Over-all magenta reds, blacks and golds, bluish whites, good slightly warm blue sky; dull, dark greens
Dynachrome 64	64	35mm (20 and 36 exp.) 126 (20 exp.)	Slightly orange reds; good blacks and golds; brilliant whites; good blue sky; excellent, bright greens
Ektachrome X	64	35mm (20 and 36 exp.) 120, 126 (20 exp.) 127,620,828	Good reds; clean blacks; clean, cold whites; brilliant blue sky; slightly bluish greens
High Speed Ektachrome Improved	160	35mm (20 and 36 exp.) 120, 126 (20 exp.)	Magenta reds and blacks; slightly greenish whites; slightly pale sky; cold bluish greens
Kodachrome II	25	35mm (20 and 36 exp.) 828	Good reds; clean blacks; slightly washed out golds; clean whites; brilliant blue sky; excellent greens
Kodachrome X	64	35mm (20 and 36 exp.) 126 (20 exp.) 828	Magenta reds, blacks and golds; slightly pinkish whites and sky; slightly pale greens.

Source: (23)

in the infrared sensitive layer (16).

Infrared color film, exposed through a yellow filter, seldom requires special focusing of the camera lens because the image is made up of both visible and infrared radiation (16). The use of a deep red filter with this film may require a lens adjustment for infrared focus.

Because of the infrared sensitivity, and because photo-electric light meters respond to visible light only, exact film speeds can not be assigned. Exposure tests should be made to determine the proper exposure (16).

Ektachrome Infrared Aero Film, type 8443 is a infrared color film produced by Eastman Kodak Company. It is available in 35-mm, 20 exposure rolls. When exposed through a yellow filter it renders healthy deciduous green foliage red and diseased or deficient foliage blue-green. The film data sheet supplied with the film suggests that exposure tests begin with an ASA speed of 100 through a No. 12 (minus-blue) filter (16). Good results have been obtained by Professor Gerlach at the University of Montana using an ASA of 100 through a No. 8 (K-2) filter and an ASA of 50 through a No. 25 (A) filter.

Infrared color film is most useful where natural color variations are the basis for successful interpretation. It has been used successfully for the detection of unhealthy foliage in forestry and agriculture (3), for comparative analysis of natural and cultural geographic features (36) and for many other purposes in the earth sciences.

Film Applications. Jenson and Colwell (12) and Schulte (26) have pointed out the necessity for film choice to be based on the objectives of the project. Small camera photography provides a means by which the resource manager can economically conduct tests to determine the film that will provide him with the needed information.

Appendix A, page 64 is an annotated bibliography of past work concerning film and film-filter comparisons. It is not a complete listing of work done, but it does provide suggestions to those who wish to conduct further studies.

Film Handling. The Manual of Color Aerial Photography (1) has the following recommendations for the storage of unprocessed and processed film.

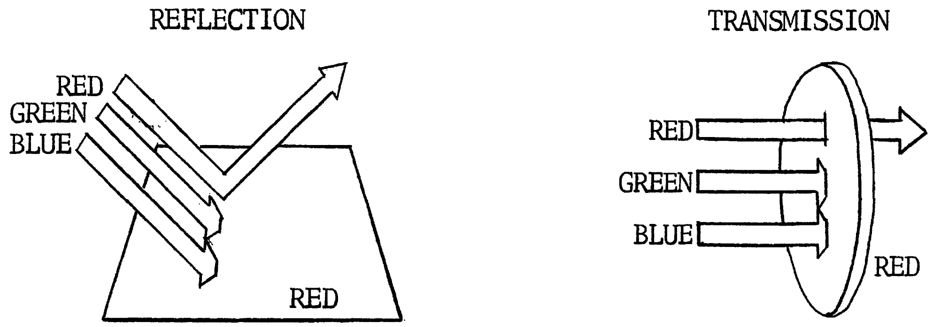
All photographic films are perishable products which are affected by high temperatures and high relative humidities. Color films are affected more than black and white films because the three emulsion layers react differently to heat and moisture. Exposed but unprocessed film is affected more than unexposed film.

Unexposed film is normally packaged in containers that require no further protection from moisture until the package is opened. However, it is still susceptable to high temperatures and should be kept where temperatures do not exceed 70 degrees Fahrenheit. If the film must be stored after the package is broken, it should be kept in a place where the relative humidity is between 40 and 60 percent and the temperature is below 70 degrees F. Packaged, unexposed film that must be kept for a long period of time is best stored in a freezer at temperatures between +10 and -10 degrees F. Film frozen in this manner must be removed and allowed to reach room temperature before the package is opened to prevent moisture from condensing on the emulsion. Color film, however, should not be kept past the expiration date because adverse conditions between refrigeration and exposure or between exposure and processing could cause unsatisfactory results.

Processed films, especially color, should be stored in a dark, cool, dry area away from chemical fumes. The dyes in color film are most affected by light, moisture and heat and will fade if not stored properly. The ideal conditions are temperatures between 60 and 70 degrees F and a relative humidity of 25 to 50 percent.

Filters

A photographic filter is a disk of colored glass or colored gelatin which absorbs a portion of the visible spectrum and transmits the rest of the spectrum. As stated in the discussion of film, white light is made up of all colors of the rainbow, which in turn are mixtures of the primary colors red, blue and green. An apple appears red because it absorbs blue and green light and reflects red. A red filter appears red because it absorbs (subtracts) green and blue light and transmits red light (figure 20). In a similar manner a yellow filter absorbs blue light and appears yellow because of the mixture of red and green, and a green filter absorbs red and blue and transmits green light.



Object absorbs green and blue, looks red.

Filter absorbs green and blue, looks red.

Figure 20. Illustration of light reflection and transmission (15)

There are two types of filters used for aerial black and white photography. They are: light controlling filters and polarizing screens. Light controlling filters reduce the light scattering effects of aerial haze and enhance contrast between objects which photograph in similar gray tones. Polarizing screens are used to minimize reflections from foliage, wood, water and other nonmetallic surfaces.

Two filters are commonly used to secure color photography from the air: skylight (haze) filters and polarizing screens.

Light Controlling Filters. Filters for controlling light are produced in five hues: yellow, green, orange, red and blue. A yellow filter is used with panchromatic film for haze cutting and for true gray tone rendition of colored objects. A red filter is normally used with infrared black and white film to obtain infrared rendition. Red filters can also be used with panchromatic and infrared color films to enhance tonal contrasts between objects. A green filter has been used with panchromatic films for forest survey work. Strandberg (31) has used a green filter with infrared color film for water penetration and interpretation of underwater objects.

Aerial color photography must be filtered to reduce the effects of haze. Atmospheric haze scatters mostly short wavelength light (ultraviolet, violet and blue), some green and very little red. The scattering of blue light is what the human eye senses and recognizes as haze. The ultraviolet light is invisible. Since all photographic materials are sensitive to violet and ultraviolet light, aerial photographs record more haze than is visible.

Skylight (UV) filters are designed for use with daylight color films to reduce the bluish cast caused by the scattered ultraviolet, violet and blue light rays. The filter is clear and does not significantly reduce the amount of image forming light that reaches the film and therefore requires no increase in exposure (see filter factors).

Polarizing Screens. Light rays normally vibrate in all directions. However, when light is reflected from shiny surfaces such as water, foliage and water droplets in the air, it is polarized (vibrates in one direction) (24). A pola-screen or polarizing filter distinguishes between light vibrating in one direction and light rays vibrating at right angles to that direction. It transmits one and rejects the other, but has no effect on color rendition. A pola-screen is useful for aerial photography of bodies of water (30) and other reflective surfaces. The use of a pola-screen increases the color saturation in foliage.

Filter Factor. Filters reduce the amount of light that reaches the film. It is necessary to compensate for this light reduction by increasing the exposure. Depending on the amount of light that is absorbed, filters are assigned factors which indicate the amount an unfiltered exposure must be increased to provide an equivalent exposure with the filter. This can be done in three ways: increase the lens opening, decrease the shutter speed or modify the nominal film speed (24).

For example a yellow (minus-blue) haze cutting filter has a filter factor of two for panchromatic film in sunlight. In the first method, to increase the exposure by increasing the lens opening, remember that one full lens stop increases the exposure 100 percent or doubles it. On modern cameras, the full stops are: 22, 16, 11, 8, 5.6, 4, 2.8, 2, 1.8, and 1.0 (24). Therefore a meter reading indicating an unfiltered exposure of f/4 for panchromatic film would require that the film be exposed at f/2.8 with the minus blue filter. For a filter with a factor of 4, the aperture would be set at f/1.8.

In the second method, simply multiply the indicated shutter speed by the filter factor to increase the exposure. For example, using the filter factor of 2 and an unfiltered shutter speed of 1/500th of a second, the filtered shutter speed would be 1/250th of a second (2 X 1/500). The aperture is left unchanged.

In the third method, the filter factor is applied to the recommended film speed. The modified film speed is used to obtain light meter readings for the exposure. The film speed must be decreased to increase the exposure, therefore the film speed without filter is divided by the filter factor. Thus, using Kodak Plus-X Pan film, (ASA 160) and a filter having a factor of 2, the exposure meter would be set at an ASA of 80 to determine the correct filtered exposure. This method can be used only with known filter factors. It is not possible to obtain a meter reading through the filter and use the resulting decrease in exposure as a measure of the filter factor, because the factor is partly dependent upon film sensitivity (24).

Table 9 lists the common filters used for black and white panchromatic aerial photography. Table 10 lists haze filters for daylight color films. Some manufacturers use letter designations and some use number designations to identify their filters. Table 9 lists letters first and numbers second.

Table 9. Filters for Panchromatic Black and White Film

Filter Letter	Filter No.	Filter Color	Filter Factor	Purpose
Aero 1	3	Light Yellow	1.5	Haze penetration
K2	8	Yellow	2.0	Haze penetration, gives correct gray-tones
Minus-blue	12	Yellow	2.0	Greater haze penetration
G	15	Deep Yellow	3.0	Haze penetration and high contrast
A	25	Red	8.0	Greatest haze penetration, extreme contrast
Pola-Screen		Neutral Gray	4.0	Eliminates surface reflections, unwanted hotspots. Used with all types of black & white or color films. Exposure depends on hours of day & amount of light after glare has been penetrated.

Source: (15,32)

Table 10. Haze Filters for Daylight Color Films*

Name	Effect
Sky 1A	Can be used at all times, reduces blue and adds warmth
Haze 1	Reduces excess blue caused by haze and ultraviolet rays.
UV 15	Haze Correction
UV 17	Greater haze correction

* No exposure increase required.

Source: (32)

SUMMARY

This paper presents a guide for obtaining aerial photographs with small cameras from light aircraft. It is directed to resource managers, knowing that resource management presents many problems, some of which are not readily or easily solved. The use of aerial photographs as an aid in solving these problems, or in the carrying out of everyday duties, is now almost commonplace. The techniques described in this paper are offered as an additional tool for the resource manager's tool box.

Small camera vertical aerial photographs are usable in virtually as many ways as conventional aerial photography. They are obtained in the same way and they provide the same type of information, sacrificing only high precision and high quality. They can be taken by almost anyone with only a little preparation and a minimum of equipment. Other advantages include economy, an opportunity to experiment and availablility of current information.

As an example of economy, the cost of small camera coverage for the flight planned on page 21 is figured here. The area is approximately 30 miles from the airport. The costs indicated are derived from local businesses.

Film cost:

1 - roll Panatomic-X, 20 exposure	$0.83
1 - roll Panatomic-X, 36 exposure	1.25
Processing, 2-rolls @ $0.50	1.00
48-5X7 inch prints @ $0.65/print	31.20
	$34.28

3-rolls Kodacolor-X, 20 exp. @ 1.95/roll	\$5.85
Processing, 3 rolls @ 1.25/roll	3.75
48-5X7 inch prints @ 1.25/print	60.00
	\$69.60

Aircraft cost:
Cessna 180 - with pilot \$30.00/hour

Fly Panatomic only - one hour	\$30.00
film cost	34.28
Total	\$64.28
5,120 acres covered - cost/acre	\$00.012

Fly Kodacolor only - one hour		\$30.00
	film cost	69.60
		\$99.60
5,120 acres covered - cost/acre		\$00.019

Costs of conventional aerial photo coverage of an area this small would be prohibitive. According to Avery (5) coverage of 25 square miles at a scale of 1:12,000 with panchromatic film is \$42.00 per square mile or \$0.065 per acre. The fixed costs would make coverage of areas smaller than 25 square miles even higher.

The low cost and ease of securing small camera photography, allows the potential user to obtain coverage on more than one film type and compare results. In this way, the most useful film type can be determined.

Finished prints can be obtained in two to four days. This makes current information available quickly and answers one of the most frequent complaints of existing conventional photography - dated information.

As Professor George Thomson (33) stated, "We are prone to stretch ourselves to use expensive and sophisticated equipment when we have not yet exhausted the working potential of materials more readily available."

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APPENDIX

APPENDIX A

Film Studies
A Selected Bibliography

Anson, Abraham. 1966. "Color Photo Comparison," Photogrammetric Engineering, 32(2), pp. 286-297.
Three films were compared (panchromatic, color and Ektachrome Infrared) for interpretation and identification of drainage features, vegetation and soils as well as cultural features such as roads, railroads and buildings. The limited study showed Ektachrome Infrared to be superior to color and panchromatic for mapping vegetation and drainage features. Color was superior for mapping soils and cultural features.

Becking, R.W. 1959. "Forestry Application of Aerial Color Photography," Photogrammetric Engineering, 25(4), pp. 559-565.
A general discussion advocating the use of aerial color photography for forestry application. Pointed out that color quality is adversely affected by haze and increased flying height. Large scale color photography has the greatest value for intensive management purposes. Where photo interpretation is dependent upon true color rendition, color photography has inherent advantages over black and white.

Benson, M.L. and W.G. Sims. 1967. "False-Color Film Fails in Practice," Journal of Forestry, 65(12), p. 904.
Kodak Ektachrome Infrared Aero Film was tested in Australia to detect diseased or damaged foliage. Past studies by others have shown diseased or damaged foliage to be rendered blue or blue-green by infrared color film. However, tests by these authors have failed to produce the predicted effects. Instead, relatively true renditions of color have resulted.

Cooper, Charles F. and Freeman M. Smith. 1966 "Color Aerial Photography: Toy or Tool?" Journal of Forestry, 64(5), pp. 373-378.
Color aerial photography should be considered for routine resource inventories because of improvements in resolution and color balance. Vegetation interpretation is made easier because of the great information content of color. However, color is more expensive than panchromatic and more is required in exposure, processing and selection of season. Transparencies are recommended because of better resolution and color balance.

Fischer, William A. 1958. "Color Aerial Photography in Photogeologic Interpretation," Photogrammetric Engineering, 24(4), pp. 545-549.
Preliminary results of a continuing investigation into the geologic uses of color aerial photography by the U.S. Geological Survey are presented. Aero Ektachrome color transparencies and Eastman color negative photographs were compared with black and

white photography of an area near Albuquerque, New Mexico. Some geologic features that are recognizable on conventional black and white photography, cannot be traced with assurance. Black and white prints made from Aero Ektachrome show more continuity and full color photography shows much more continuity and clarity. The studies suggest that color photography may be of significant value in detailed geologic mapping.

Francis, D.A. 1957. "The Use of Aerial Photographs in Tropical Forests," Unasylva, 11(3), pp. 102-109.
Scale and film-filter combinations are discussed and mapping techniques are described for type mapping in tropical forests. The best and cheapest film and filter combination was panchromatic minus-blue at scales of 1:20,000 or larger. Color aerial photography was experimented with, first using a 35-mm camera which provided promising results and then with aerial film and aerial cameras.

Haack, Paul M. 1962. "Evaluating Color, Infrared and Panchromatic Aerial Photos for the Forest Survey of Interior Alaska," Photogrammetric Engineering, 28(4), pp. 592-598.
Panchromatic and infrared (both with minus-blue filter) and color photographs were obtained of three sample strips in Interior Alaska to determine the film type best suited for vegetative interpretation. No significant difference was found between film types, but several desirable features of infrared film led to its selection.

Heller, R.C., R.C. Aldrich and W.F. Bailey. 1959. "An Evaluation of Aerial Photography for Detecting Southern Pine Beetle Damage," Photogrammetric Engineering, 25(4), pp. 595-606.
Color and panchromatic film was compared for locating and appraising insect-killed timber in North Carolina. Interpretation on the color film was more accurate. The authors concluded that color photography would be most useful where it is necessary to map the location of infested trees with a high degree of accuracy, such as an expensive bark beetle operation.

Jenson, Herbert A. and Robert N. Colwell. 1949."Panchromatic versus Infrared Minus-Blue Aerial Photography for Forestry Purposes in California," Photogrammetric Engineering, 15(2), pp. 201-223.
Panchromatic film with a minus-blue and with a green filter and infrared film with a minus-blue filter at scales of 1:20,000 and 1:15,000 were tested for interpretation of species, size, density and age-class in the California pine region and redwood region. The test indicated that panchromatic minus-blue provided easier and more accurate identification of species, size and density. It was concluded that the film-filter combination best suited for a particular project is dependent upon the objectives of that project.

Lund, H.G., G.R. Fahnestock and J.F. Wear. 1967. Aerial Photo Interpretation of Understories in Two Oregon Oak Stands. Pacific North-

west Forest and Range Experiment Station, Research Note No. PNW-58.
Ektachrome Aero and Ektachrome Infrared Aero Photography at scales of 1:20,000 and 1:3,500 were tested to determine the feasibility of interpretation of understory vegetation. The study indicated that it is possible to interpret understory vegetation from natural-color aerial photographs.

Maruyasu, Takakaqu and Motomitsu Nishio. 1960. Experimental Studies on Color Aerial Photographs in Japan. Report of the Institute of Industrial Science, University of Tokyo. Vol. 8, No. 6.
The study included; the taking of aerial photographs, selection of instruments, effects of haze, reproduction of photographs, cartgraphic application and interpretation. Concluded that color is superior to monochromatic photos in all respects, especially in photo interpretation.

Meyer, M.P. and L.H. Trantow. 1961. "A Test of Polaroid Variable-Color Filters for Forest Aerial Photography," Photogrammetric Engineering, 27(5), pp. 703-705.
Minnesota conifer-deciduous tree tonal relationships in the green and yellow portions of the visible spectrum were examined using Polaroid variable-color filters. Summer infrared minus-blue and fall panchromatic minus-blue photography was superior although the variable-filter summer panchromatic photography showed some improvement over summer panchromatic minus-blue.

Mott, P.G. 1966. "Some Aspects of Colour Aerial Photography In Practice and Its Applications," The Photogrammetric Record, Vol. V, No. 28, p. 221.
The advantages and disadvantages of color reversal film, color negative film and false-color film were discussed. The author expressed his confidence that false-color film will soon entirely replace black and white infrared and gave his reasons. He stated that false-color is superior to natural color for forestry and some vegetation studies.

Mullins, L. 1966. "Some Important Characteristics of Photographic Materials for Air Photographs," The Photogrammetric Record, Vol. V, No. 28, pp. 240-270.
Discussed the types of materials available, their properties and applications. Concluded that: 1) there is a need for an international method of determining and expressing aerial film speeds, 2) optimum combinations of film and developer for black and white processing should receive greater consideration, and 3) color photography offers important advantages, which outweigh the disadvantages, therefore the system should be examined in more detail.

Schulte, O.W. 1951. "The Use of Panchromatic, Infrared and Color Photography in the Study of Plant Distribution," Photogrammetric Engineering, 17(5), pp. 688-709.

Discussed vegetation as a photographic subject, vegetation on the aerial photograph, aerial panchromatic, infrared and color photography and species keys. Concluded that infrared is preferable for species recognition in Southwestern Canada, however, film choice depends on region, scale desired and season when photographed. Color is preferable for special problems, such as, disturbance of vegetation and consequent browning.

Smith, John T., Jr. 1963. "Color - A New Dimension in Photogrammetry," Photogrammetric Engineering, 29(6), pp. 999-1013.
Discussed the use of color aerial photography by the U.S. Coast and Geodetic Survey. The application of color photography to a number of interpretative problems is presented with illustrations. Concluded that color aerial photography has great possibilities for improvement of photo-interpretation.

Spurr, Stephen H. 1949. "Films and Filters for Forest Aerial Photography," Photogrammetric Engineering, 15(3), pp. 473-481.
Compared oblique photography taken from high ground elevations in New England using combinations of four film types and seven filters. Of the variables tested, film type had the greatest effect on the resulting picture.

Tarkington, R.G. 1953. "An Aspect of Color Photography and Interpretation," Photogrammetric Engineering, 19, pp. 418-420.
The spectrophotometric characteristics of an object photographed and the spectrophotometric characteristics of the dyes that form the image of that object have no simple direct relationship. The author reviews the three-color aspect of human vision and its application to color photographic process and recommends that to determine the utility of color for interpretation, photograph the objects with the color process to be used.

Tarkington, R.G. and Allan L. Sorem. 1963. "Color and False Color Films for Aerial Photography," Photogrammetric Engineering, 29(1), pp. 88-95.
Two new films, Kodak Ektachrome Aero and Kodak Ektachrome Infrared Aero, were discussed and compared with older similar products they replace. Also discussed was color reproduction by the photographic process.

Umbach, Melvin J. Lt. Cdr. 1968. "Color for Metric Photogrammetry," Photogrammetric Engineering, 34(3), pp. 265-272.
Tests conducted by the U.S. Coast and Geodetic Survey to evaluate the metric fidelity of several brands of color film are presented. Results showed no significant difference in stability between color and panchromatic systems.

Wear, John F. 1960. "Interpretation Methods and Field Use of Aerial Color Photos," Photogrammetric Engineering, 26, pp. 805-808.

The lack of suitable office and field equipment and field interpretation methods has hampered acceptance of aerial color photography. Color interpretation techniques and film handling procedures are presented as well as a description of a portable light table designed by the Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Welch, R. 1966. "A Comparison of Aerial Films in the Study of the Breidamerkur Glacier Area, Iceland," Photogrammetric Record, Vol. V, No. 28, pp. 289-306.
Color, false color, infrared and panchromatic photography was obtained for comparison of the interpretation value of the four film types for interpretation of glacierized areas. The comparison indicated that color is superior to the other three film types.

APPENDIX B

Calculation of the Angle of Elevation of the Sun

The angle of elevation of the sun (X) is calculated from the following formula (29):

$$\sin X = (\cos a)(\cos b)(\cos c) \pm (\sin a)(\sin b)$$

where _a_ is the sun's declination or latitude on the day of photography, _b_ is the known latitude of the photography, and _c_ is the difference in longitude between the position of the sun and the position of the photography. In the Northern Hemisphere, the sign between the two parts of the equation will be plus between March 21 and September 23 and minus between September 23 and March 21. Figure 21 illustrates the angles involved.

The sun's declination _a_ is obtained from a current solar ephemeris. The latitude of photography _b_ can be obtained from the flight map or other map which gives latitude and longitude.

The difference in longitude _c_, also called the hour angle, is calculated in the following manner. First the time of the proposed photography is converted to Greenwich Civil Time by adding one hour for each 15 degrees of longitude west of Greenwich or for each time zone. Therefore, seven hours must be added to convert Mountain Standard time to Greenwich Civil Time (the central meridian of Mountain Standard Time zone is 105 degrees). Because the sun varies in its course it is usually a little ahead or a little behind schedule at noon Greenwich Time, and therefore the calculated Greenwich Civil

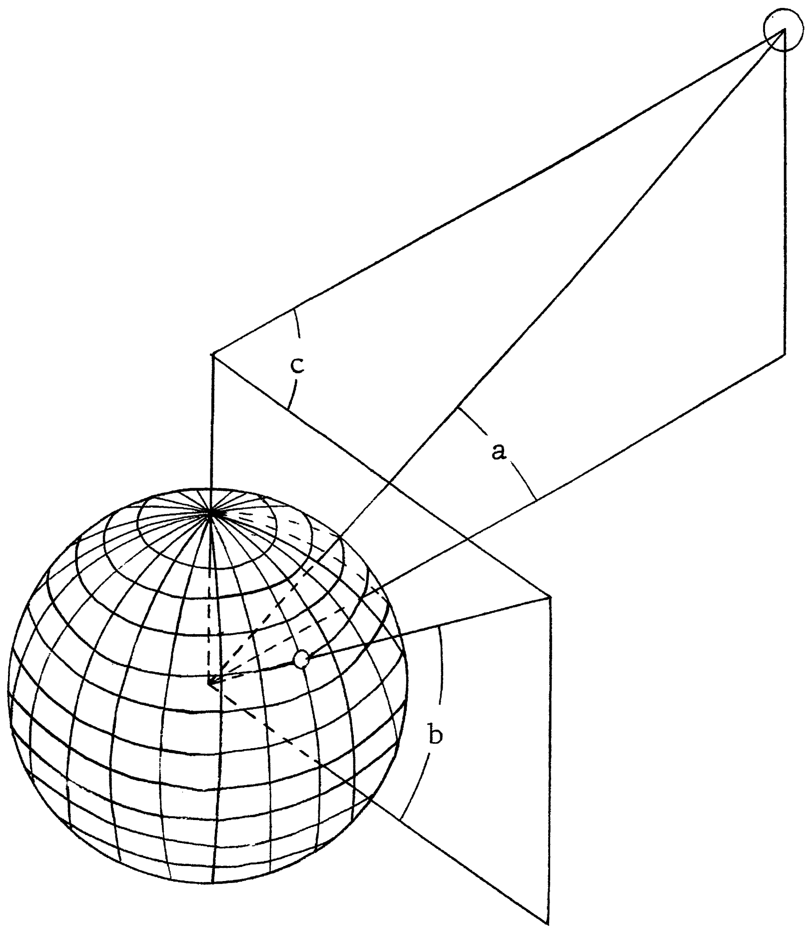


Figure 21. Angles involved in the determination of the sun's elevation (29).

Time must be corrected for this variation. This correction, called the equation of time is obtained from a current solar ephemeris and is either added or subtracted according to the indicated sign. The corrected solar time is then converted to longitude by multiplying by fifteen. (The sun moves west at the rate of fifteen degrees an hour or one degree in four minutes.) The difference in longitude or hour angle c is determined by subtracting the longitude of the sun from the longitude of the photography as determined from a map.

The following is a form which can be followed for the calculation of the sun's elevation. Included is an example for Missoula, Montana.

Calculation of the Sun's Elevation

Sun's Declination on Day of Photography (angle a)

1. Date............................. June 26, 1968
2. Angle a...................................23°22'
3. Sin a.................................... .397
4. Cos a.................................... .918

Latitude of Photography (angle b, from map)

5. Latitude..................................46°50'
6. Sin b.................................... .729
7. Cos b.................................... .684

Longitude of the Sun at Time of Photography

8. Time of Photography...................12:00 MST
9. Hours to Change to Greenwich Civil Time....+7:00
10. Greenwich Civil Time...................... 7:00
11. Equation of Time.......................-0:02:39
12. Corrected Solar Time...................... 6:57
13. Times 15 to convert to Longitude.........104°15'

Hour Angle (angle c)

14. Longitude of Photography (from map)......114°00'
15. Longitude of the Sun (same as 13)........104°15'

16. Difference or Hour Angle c. . . . . 9°45'
17. Cos c. 968

Sin X = (cos a)(cos b)(cos c) ± (sin a)(sin b)

Sin X = (.918)(.684)(.986)+(.397)(.729)

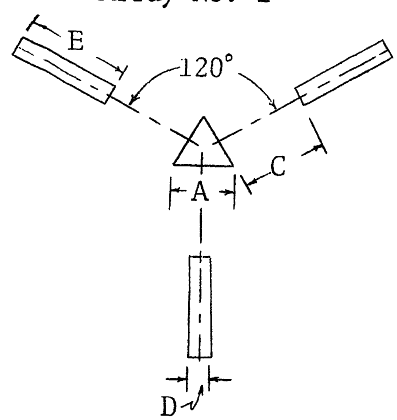
Sin X = .908

X = 65°14'

APPENDIX C

Specifications for Ground Control Targets

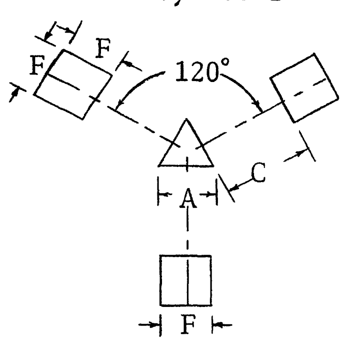
Array No. 1



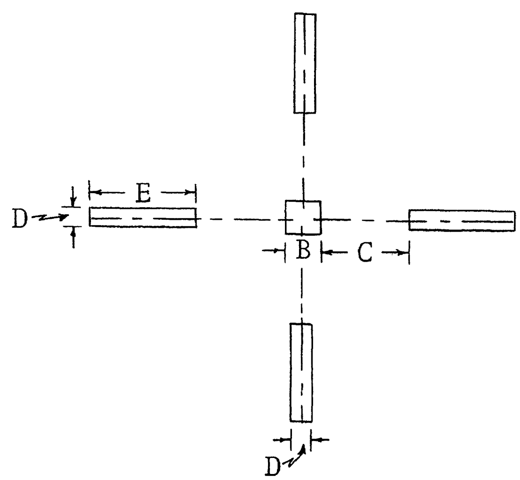
Note:

1. The dimensions and centering of center panel are critical.
2. Panel array No. 1 is preferred. Select array that makes best application of field conditions.
3. Use white muslin, plastic or white wash.

Array No. 2



Array No. 3



Panel and Spacing Dimensions (feet)

Photo Scale	A	B	C	D	E	F
1:10,000	3	2	4	1	10	3
1:20,000	6	3	8	2	12	5
1:30,000	9	4	12	3	15	8
1:40,000	12	5	15	4	20	10
1:50,000	15	8	20	5	25	12
1:60,000	18	10	25	6	30	15

Figure 22. Target arrays used for aerotriangulation (1).

APPENDIX D

Form 1

PHOTO MISSION PRE-FLIGHT DATA

Project ______________________ Open Dates ______________

Area To Be Photographed ______________________________

Purpose or Use ______________________________________

Film(s) To Be Used ________________ Quantity ______________

Camera ____________ Lens: Speed ________ Focal Length __________

Scale ____________ Flying Height ________________________

Ave. Ground Elevation ____________ True Altitude ______________

Direction of Flight Lines(True Bearing,Degrees) ______________

Exposure Interval(seconds) _____ Sidelap _____ Endlap __________

Exposures Per Line ________________ Total Exposures __________

Flight Line Control __________________________________

Aircraft ______________ Desired Ground Speed ______________

Equipment Readiness Check:

Camera and Lens ________________

Filter(s) ________________

Timer ________________

Light Meter ________________

Camera Level Check ________________

Remarks: ____

____

____

____

____

APPENDIX D

Form 2

PHOTO MISSION FLIGHT DATA

Project ______________________________ Date ______________

Time: Offground ______________________ Onground ______________

Photo Runs Started ______________ Photo Runs Ended ______________

Film(s) Used ______________________ Quantity ______________

Filter(s) Used ____________________ Factor(s) ______________

Camera __________________ Lens: Speed ________ Focal Length ________

Shutter Speed ________________ Aperture ______________________

Scale ________________________ Flying Height __________________

Ave. Ground Elevation ______________ True Altitude ______________

Aircraft ____________________ Ground Speed ____________________

Exposure Interval ______________ Exposures/Line __________________

Flight Line Control ____

Direction of Flight Lines (True Bearing, Degrees) ______________

____

Weather Conditions ____

____

Pilot ____________________ Cameraman ______________________

Timer ____________________ Others ________________________

Remarks: ____

____

____

____

____

APPENDIX D

Form 3

PHOTO MISSION POST FLIGHT DATA

Project ______________________ Date ______________

Description of Area ______________________

Film/Filter Combinations ______________________

Camera ______________ Lens: Speed ________ Focal Length ________

Light Value(s) ________ Shutter Speed ________ Aperture ________

True Altitude ______________ Flying Height ______________

Ave. Ground Elevation ______________ Scale ______________

Aircraft ______________ Ground Speed ______________

Exposure Interval ________ Endlap ________ Sidelap ________

Exposures/Line ______________ Total Exposures ______________

Photo Numbers Assigned ______________________

Photo Analysis:

Coverage ______________ Photo Quality ______________

Crab ______________ ______________

Tilt ______________ ______________

Cost: Planning ______________ Plane&Pilot ______________

Wages ______________ Film&Processing ______________

Other ______________ Total Cost ______________

Acreage ______________ Cost/Acre ______________

Remarks: ______________________

____

____

____